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...NTAL STATION, SUFFIELD, ALTA.

SUFFIELD REPORT NO. 121

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CASUALTY PRODUCING POWER OF UNTHICKENED MUSTARD GAS SPRAYED FROM LOW ALTITUDES UNDER TEMPERATE WEATHER CONDITIONS

S U M M A R Y

1. A series of trials has been carried out at Suffield at the request of the U.S. Project Co-ordination Board with the purpose of investigating under temperate weather conditions the casualty producing power of unthickened HS (Levinstein).

2. On each of three trials an M.10 tank charged approximately 325 lbs.of HS(Levinstein) dyed red was functioned from the wing stowage of a Boston (A 20 J) aircraft flying crosswind at approximately 220 mi/hr at a height of 35 to 100 ft. The track of the A/C was 30 yards upwind of a sampling layout of filter paper assemblies and chloroform-filled plates. The latter were used to obtain samples of the spray for determination of loss of H by evaporation during the fall of the spray.

3. Observers were stationed at a number of points within the area expected to be contaminated by each spray. The positions were, in general, from 90 to 150 yards downwind of the track of the A/C, and from 100 to 700 yards across wind from the point where the M.10 tank was functioned. A total of 83 observers were exposed on three trials.

4. During the spraying the observers stood facing downwind. They were dressed as follows:

Battle-dress, non-impregnated.
Shirts,long-sleeved, cotton.
Anklets, socks and boots.
Respirators at the "Gas" position.
(In the first trial only, the twenty observers also wore long-limbed,winter-weight underwear, non-impregnated.)

Impermeable clothing, (coat and trousers) was worn over the battle-dress, impermeable hood over the head, and rubber gloves on the hands.

5. Windows, 4 inches x 4 inches, were cut in the impermeable clothing at the following positions:

(a) At the back of each shoulder, where the clothing is normally in close contact with the skin. (All Trials).

(b) Over each buttock where clothing is in close contact with the skin and is pressed against the skin in sitting down. (Field Exp. 229 only).

(c) Over each calf where the clothing is usually loose over the skin. (Field Experiment 229 only).

(d) One window in the centre of the back, just above the belt on the loosely fitting part of the battle-dress blouse. (Field Experiments 243 and 251 only).

(e) One window at the level of each collar bone, just above the breast pocket. (Field Exp. 251 only). The edges of the windows were sewn down to the battle-dress in all cases.

6. At each observer position four filter paper assemblies were placed on the ground in proximity to the observer to determine the ground contamination at that point. On the second and third trials a filter paper assembly was fastened to the back of each observer just below the waist line to determine the density of contamination on the observers.

7. After the spray had fallen the observers moved off the contaminated area and the impermeable clothing was removed. The remainder of the clothing was worn for four hours. During this time approximately half of the observers took part in outdoor station fatigues, (raking, shovelling gravel, digging, etc.) while the remaining men lay or sat about in a room at 75°F.

8. From examination at various times after the spray the observers were classified as probable casualties or probable non-casualties. The decision as to whether or not an observer was classed as a casualty was based on the severity of the lesions which it was considered would have occurred had the observer been exposed without any part of his body protected by impermeable clothing, extrapolating from the lesions resulting from exposure of the various 4 x 4 inch areas. It may be noted that a few observers became actual casualties although, except for the windows, they were protected by impermeable cloth

9. Meteorological Conditions

	Trial 1	Trial 2	Trial 3
Air Temp.	19.4°C(67°F)	16°C(61.5°F)	17°C(62°F)
Ground Temp.	26.1°C(79°F)	21°C(70°F)	20°(68°)
Wind Velocity at 2 metres.	15 mi/hr.	15 mi/hr	8.4 mi/hr.
Relative Humidity	34%	67%	61%

10. The results obtained from the observers are summarized in tables I and II below.

TABLE I

Correlation of ground contamination density produced by low spray with unthickened HS Levinstein, in an 8 to 15 mi/hr. wind, with the casualty effect on observers standing in regions of various contamination densities.

Density of Ground Contamination in vicinity of observers (g/sq.m.)	Number of Observers classified as		Percentage of Observers classified as	
	Probable Casualties	Probable Non-Casualties	Probable Casualties	Probable Non-Casualties
Greater than 4.0	5[x](5)(0)(0)	0	100	0
" " 3.0, to 4.0	6[x](5)(1)(0)	1	86	14
" " 2.0, to 3.0	7 (4)(2)(1)	3	70	30
" " 1.0 to 2.0	4[x](2)(1)(1)	11	27	69
" " 0.5, to 1.0	4 (2)(0)(2)	14	22	78
" " 0 to 0.5	1 (0)(0)(1)	27	4	96
Total	27(18)(4)(5)	56		

The figures in parenthesis indicate the number of observers who, it was considered, would have become casualties, probable casualties and possible casualties respectively if they had not been wearing the impermeable clothing All have been included as casualties for the purpose of calculation. Of the figures marked [x] 2/5,1/6 and 1/4 respectively were actual casualties.

The density of ground contamination was obtained by taking the mean of the density found at four points in close proximity to the observer.

SUMMARY (Cont.)

TABLE II

Correlation of contamination density on observers' backs with the casualty effect produced on observers exposed to low spray with unthickened HS Levinstein in an 8 to 15 mi/hr. wind.

Density of Contamination on Observers' backs. (g/sq.m.)	Number of Observors Classified as: Probable Casualties	Probable Non-casualties	Percent of Observer exposed classified as: Probable Casualties	Probable Non-casualties
Greater than 4.0	12 (8)(3)(1)	1	92	8
" 3.0, to 4.0	3 (1)(1)(1)	2	60	40
" 2.0, to 3.0	1 (0)(0)(1)	4	20	80
" 1.0, to 2.0	2 (1)(0)(1)	10	17	83
" 0.5, to 1.0	0 0	6	0	100
" 0 to 0.5	0 0	21	0	100
Total	18 10 (4)(4)	44		

The figures in parenthesis indicate the number of observers who, it was considered, would have become casualties, probable casualties and possible casualties respectively if they had not been wearing the impermeable clothing. All have been included as casualties for the purpose of calculation.

11. The following conclusions (based on extrapolation as regards physiological results) were drawn from the data collected on the three trials.

* (a) Casualties among troops sprayed with unthickened Levinstein HS in an 8 to 15 mi/hr. wind, at an air temperature of from 60 to 70°F. and wearing respirators, unimpregnated battle dress and cotton shirts will probably be infrequent if the ground contamination density in the vicinity of the individual man is less than 1 g/sq.m. Under similar circumstances it is probable that approximately 50% casualties will result from exposure of troops in regions where the ground contamination is 2 g/sq.m., while the casualty rate will be high if the ground contamination density exceeds 3 g/sq.m..

* (b) Of troops wearing respirators, battle dress and cotton shirts, who become contaminated with mustard as a result of exposure to unthickened HS (Levinstein) sprayed from low heights, 50% will probably become casualties if the density of contamination on their clothing is approximately 3 to 4 grams per sq.m. The casualty rate will probably be high among troops contaminated to an extent much in excess of 4 g/sq.m. and will be low if the contamination density on their clothing is less than 3 g/sq.m..

(c) When men are exposed to unthickened mustard gas spray, (droplets 0.2 to 0.4 mm. diameter) while standing facing downwind in windspeeds of 8 to 15 mi/hr., the density of contamination on their backs will be approximately 60% of the density calculated from the ground contamination in the immediate vicinity of the observers and from the dominant drop size.

(d) One M 10 tank, functioned from an A/C flying 50 ft. above ground at a speed of 215 mi/hr. will contaminate an area of approximately 20,000 sq. yds. to a density in excess of 2 g/sq.m. when the wind at 2 metres is 8 to 15 mi/hr. Troops wearing respirators, battle-dress and cotton shirts exposed within this area stand approximately a 50% chance of becoming casualties as a result of burns from liquid-contaminated clothing.

(e) When the air temperature is approximately 65°F., unthickened HS Levinstein sprayed from heights of the order of 50 to 100 ft. will fall to the ground without serious evaporation in flight. The overall loss by evaporation before the mustard reaches the ground is likely to be less than 15 percent.

* It is assumed that the troops will wear their clothing for 4 hours after it has been contaminated.

for H.M. Barrett
(E. Ll. Davies)
Chief Superintendent,

EXPERIMENTAL STATION, SUFFIELD, ALBERTA

SUFFIELD REPORT NO. 121.

COPY NO. _____

DATE 3 NOVEMBER 44

CASUALTY PRODUCING POWER OF UNTHICKENED MUSTARD GAS SPRAYED FROM LOW ALTITUDES UNDER TEMPERATE WEATHER CONDITIONS

REFERENCE: Field Experiments Nos. 229,243,251.
D.C.W.& S. Project S.143

INTRODUCTION:

1. Investigations carried out in the U.S. have indicated that unthickened HS Levinstein, when sprayed from A/C flying at low altitudes and high speeds will not shatter so excessively as to preclude its use against troops.

2. A series of trials has been carried out at Suffield at the request of the U.S. Project Co-ordination Board with the purpose of investigating under temperate conditions the casualty producing power of the contamination produced by such sprays.

3. The trials carried out at Suffield were intended to determine what density of contamination must be laid down over an area in order to render casualties any troops exposed within the area, the troops having no special gas protection other than respirators.

4. In the course of the trial some dat a on weapon performance were accumulated. These data are presented in this report as being of interest and of value to those concerned with evaluating the performance of spray weapons likely to be used for dispersing unthickened mustard.

5. The trials were carried out as Field Experiments Nos. 229,243,and 251. The general procedure and assessment technique used on these trials, and a summary of the results obtained together with discussion and conclusions are given below. Detailed reports of the above field experiments are given as Appendices I,II, and III respectively.

PROCEDURE

6. On each trial, an M 10 tank charged approximately 325 lbs. of HS Levinstein dyed red, was functioned from the wing stowage of a Boston (A20J) Aircraft, flying across wind at approximately 220 mi/hr at a height of 35 to 100 ft. The track of the A/C was 30 yards upwind of a sampling layout.

7. The ground contamination was assessed by means of filter paper assemblies laid on the ground in rows parallel to the wind direction covering a front of 100 yards across wind. The spacing of the filter papers on the layout and the downwind length of the rows varied from trial to trial.

8. The loss of H by evaporation during fall of the spray was estimated by collecing samples of the spray in chloroform in pie plates placed on the ground at a number of points on the layout. The amount of mustard gas found in each plate after the spray had fallen was estimated by the bromine tetration method. The amount of original dyed HS charging was determined colorimetrically.

x This method was developed from suggestions made by Dr. Northrup.

9. Observers were stationed at a number of points within the area expected to be contaminated by each spray. The positions at which observers were stationed were not the same in all trials, but in general were from 90 to 150 yards downwind of the track of the A/C - (60 to 120 yards downwind of the upwind edge of the layout), and from 100 to 700 yards across wind from the point where the M 10 tank was functioned. Twenty observers were exposed on Field Experiment 229, 28 on Field Experiment 243 and 35 on Field Experiment 251.

10. During the spraying the observers stood facing downwind. They were dressed as follows:

Battle dress, non - impregnated.
Shirts, long - sleeved, cotton.
Anklets, socks and boots.
Respirators at the "Gas" position.
(In Field Experiment 229 only, the observers also wore underwear, long - limbed, winter weight, non-impregnated).
Impermeable clothing (coat and trousers) was worn over the battle - dress, an impermeable hood over the head, and rubber gloves on the hands.

11. Windows, 4 inches x 4 inches, were cut in the impermeable clothing at the following positions:

(a) At the back of each shoulder, where the clothing is normally in close contact with the skin. (All Trials).

(b) Over each buttock where clothing is in close contact with the skin and is pressed against the skin in sitting down. (Field Experiment 229 only).

(c) Over each calf where the clothing is usually loose over the skin. (Field Experiment 229 only).

(d) One window in the centre of the back, just above the belt on the loosely fitting part of the battle - dress blouse. (Field Experiment 243 and 251 only).

(e) One window at the level of each collar bone, just above the breast pocket. (Field Experiment 251 only). The edges of the window were sewn down to the battle - dress in all cases.

12. At each observer position four filter paper assemblies were placed in proximity to the observer to determine the ground contamination at that point. The disposition of these papers was not the same on all trials. For details see Appendices I, II and III.

13. On Field Experiments 243 and 251, a filter paper assembly (with circular filter paper surface 8 inches in diameter) was fastened to the back of each observer just below the waist line to determine approximately the density of contamination which fell on the observers' backs.

14. On Field Experiment 229 vapor sampling was carried out at 21 inches height, on lines 110 and 150 yards downwind of the A/C track.

15. After the spray had fallen the observers moved off the contaminated area and the impermeable clothing was removed. The remainder of the clothing was worn for four hours. During this time approximately half of the observers took part in outdoor station fatigues, (raking shovelling gravel, digging, etc.) while the remaining men lay or sat about in a room at 75°F.

16. From examination at various times after the spray the observers were classified as probable casualties or probable non-casualties. The decision as to whether or not an observer was classed as a casualty was based on the severity of the lesions which it was considered would have occurred had the observer been exposed without any part of his body protected by impermeable clothing, extrapolating from the lesions resulting from exposure of the various 4 x 4 inch areas. It may be noted that a few of the observers became actual casualties although, except for the windows, they were protected by impermeable clothing.

RESULTS:

17. Meteorological Conditions

	F.E. 229	F.E. 243	F.E. 251
Air Temp.	19.4°C (67°F)	16°C (61°F)	17°C (62°F)
Ground Temp.	26.1°C (79°F)	21°C (70°F)	20°C (68°F)
Wind Velocity at 2 metres.	15 mi/hr.	15 mi/hr.	8.4 mi/hr.
Relative Humidity	34%	67%	61%

Effects on Observers

18. Of the 20 observers exposed in Field Experiment 229, 9 developed vesication of the skin corresponding to the site of the windows in the impermeable clothing they wore.

19. Of the 28 observers exposed in Field Experiment 243, only two developed vesication of the shoulders corresponding to the site of the windows in their impermeable clothing. No vesication was noted in the region of the window in the lower back.

20. Of the 35 observers exposed in Field Experiment 251, 10 developed vesication of the shoulders or back, while 6 developed pin-point vesication of the shoulders, extending down the back to the belt line in some cases.

21. Details of the physiological results obtained on the individual trials may be found as addenda to Appendices I, II, and III. Photographs of typical lesions are given in Appendix V. As mentioned in Para. 16, the classification of an observer as a probable casualty or a probable non-casualty was based on an extrapolation. In some cases the severity of the lesions was such that it could be stated with confidence that certain observers would have been casualties had they been exposed without any protection from impermeable clothing. In other cases a decision could not be made with certainty that the observers would have been casualties, but their lesions were such that there seemed to be a very good chance that this would have been the case. Consequently, observers were divided into four groups: - casualties, probable casualties, possible casualties, and non-casualties, but in summarizing the results in tabular form in this report, the first three groups have been classified as casualties.

22. The correlation of casualty effect with the contamination density on the ground near observers, and with the contamination density on the observers' backs is summarized for all experiments in Tables I and II below.

TABLE I

Correlation of ground contamination density produced by low spray with unthickened HS Levinstein, in an 8 to 15 mi/hr. wind, with the casualty effect on observers standing in regions of varied contamination densities.

(2) Density of Ground contamination in vicinity of observers (g/sq.m.)	Number of observers classified as:		Percent of observers classified as:	
	Probable (1) Casualties	Probable Non-Casualties	Probable Casualties	Probable Non-Casualties
greater than 4.0	5^{x}(5)(0)(0)	0	100	0
greater than 3.0, to 4.0	6^{x}(5)(1)(0)	1	86	14
greater than 2.0, to 3.0	7 (4)(2)(1)	3	70	30
greater than 1.0, to 2.0	4^{x}(2)(1)(1)	11	27	73
greater than 0.5, to 1.0	4 (2)(0)(2)	14	22	78
greater than 0 to 0.5	1 (0)(0)(1)	27	4	96
Total	27(18)(4)(5)	56		

(1) The figures in parenthesis indicate the number of observers who, it was considered, would have become casualties, probable casualties and possible casualties respectively, if they had not been wearing the impermeable clothing. All have been included as casualties for the purpose of calculation. Of the figures marked ^{x} 2/5, 1/6 and 1/4 respectively were actual casualties.

(2) The density of ground contamination was obtained by taking the mean of the density found at four points in close proximity to the observer. See Appendices I, II and III.

TABLE II

Correlation of contamination density on observers' backs with the casualty effect produced on observers exposed to low spray with unthickened HS Levinstein in an 8 to 15 mi/hr. wind.

(1) Density of Contamination on Observers' back (g/sq.m.)	(2) No. of Observers classified as:		Percent of Observers classified as:	
	Probable(3) Casualties	Probable Non-Casualties	Probable Casualties	Probable Non-Casualties
greater than 4.0	12 (8)(3)(1)	1	92	8
greater than 3.0, to 4.0	3 (1)(1)(1)	2	60	40
greater than 2.0, to 3.0	1 (0)(0)(1)	4	20	80
greater than 1.0, to 2.0	2 (1)(0)(1)	10	17	83
greater than 0.5, to 1.0	0	6	0	100
greater than 0 to 0.5	0	21	0	100
Total	18(10)(4)(4)	44		

Table II (Cont.)
1. See para. 13.

2. Since no filter paper assemblies were fastened to the observers in Field Experiment 229, the results of this trial cannot be included in Table II. One filter paper was lost on Field Experiment 243, hence data on only 62 observers are available.

3. See Note Table I.

23. The correlation between the ground contamination surrounding observers and the density of contamination on their backs is given for Field Experiments 243, and 251 in Table IV of Appendix II and Table III of Appendix III. From the predominant drop size found on the observers and the known terminal velocities of the drops and from a knowledge of ground contamination density and wind speed, the density of contamination to be expected on each observer's back was calculated. (Assuming that a man's back is a perfect impactor, and that turbulence of the atmosphere had no effect in a 15 mi/hr wind 0.2 mm. droplets might be expected to produce a degree of contamination on his back 6.3 times that on the ground upon which he is standing, with 0.5 mm. droplets the ratio would be 2.75). For 27 of the observers exposed on Field Experiment 243 (wind speed 15 mi/hr.) the geometric mean ratio of calculated density to observed density was 1.6. For 34 of the observers exposed on Field Experiment 251 (wind speed 8.4 mi/hr.) the geometric mean ratio of calculated to observed density was also 1.6. Results on one observer of each experiment were ignored since the density of contamination was recorded only as "trace".

Ground Contamination

24. A summary of the ground contamination achieved in the three experiments, is given in Table III. Detailed results are given in Appendices I, II and III.

TABLE III

	Field Experiment 229	Field Experiment 243	Field Experiment 251
A/C speed.	215	215	225
Spraying Height (ft.)	55	35	50
Wind Speed at 2 m. (mi/hr.)	13	15	8.4
Area contaminated in excess of 1 g/sq.m. (sq. yds.)	45000	36000	40000
2 g/sq.m.(sq. yds.)	26000	22000	21500
Total recovery on layout	45%	93%	89%
Predominant drop sizes caught on layout.	0.2 to 0.5 mm. (0.005 to 0.09 mg.)	0.24 to 0.4 mm. (0.01 to 0.05 mg.)	0.24 to 0.4 mm. (0.01 to 0.05 mg.)
Remarks:	Grid unit was 5 yds. x 100 yds. downwind of track of A/C. Considerable loss off downwind edge of layout.	Grid unit was 20 yds. x 100 yds. to a distance 190 yds. downwind of track of A/C. Drop spectrum determined only in range 130 to 190 yds. downwind of track. Relatively small amount of material fell downwind of layout.	Grid unit was 5 x 50 yds. to a distance 180 yds. downwind of track. Thence 10 x 5 yds. to a distance 280yds. downwind of track. Drop spectrum determined from 30 to 280 yds. downwind of track.

Contamination densities were based on dye recovery and take no account of evaporative loss from the spray.

25. In all experiments it was noted that the contamination obtained was not uniform but consisted of streaks running in the direction of the wind due, probably, to a varying rate of emission of charging from the M 10 tank.

Vapour Sampling

26. Under the conditions which obtained when Field Experiment 229 was carried out, the mean dosage of mustard vapour accumulated along a 1000-yard front 80 yards downwind of the upwind edge of contamination within the first four hours after spraying was approximately 450 mg. min/cu.m. Similarly the mean dosage accumulated along a 1000-yard front 120 yards downwind of the upwind edge of contamination was approximately 250 mg.min/cu.m. Detailed results are given in Table IV of Appendix I.

Analysis of the Spray.

27. The results of analyses carried out on spray samples caught in chloroform filled plates are given in detail in Table II of Appendix I, and Table II of Appendix III. On Field Experiment 229 for points 80 to 150 yards downwind of the A/C track approximately 15% of the mustard content of the spray had been lost by evaporation by the time the spray reached the ground. On Field Experiment 243 the results were rendered invalid due to the untrustworthy sample of charging used as a standard for the calibration. On Field Experiment 251 the mean loss of mustard by evaporation was 8% for points from 70 yards to 170 yards downwind of the track of the aircraft.

DISCUSSION OF RESULTS

28. The figures given in Table I., para. 22, demonstrate that for wind speeds between 8 and 15 mi/hr. there will probably be 50% casualties among troops standing in areas contaminated to the extent of approximately 2 g/sq.m. when dressed as on these experiments, but with no protection by impermeable clothing. Under similar circumstances the casualty rate will probably be very high for troops in areas contaminated more heavily than 3 g/sq.m. and very low for troops in areas contaminated to less than 1 g/sq.m.

29. The data presented in Table II suggests that of troops wearing respirators, battle-dress and cotton shirts, who become contaminated with mustard as a result of exposure to unthickened HS (Levinstein) sprayed from low height, 50% will probably become casualties if the density of contamination on their clothing is approximately 3 to 4 grams per sq.m. Casualties will probably be high among troops contaminated to an extent much greater than 4 g/sq.m., and low if the contamination density on their clothing is less than 3 g/sq.m.

30. Because the classification of observers as casualty or non-casualty depended upon an exposure of only small portions of the observers bodies to the spray, with extrapolation to the result to be expected with observers who were not partially protected by impermeable clothing, an exact definition of what is meant in this report by casualty, probable casualty and possible casualty, cannot be given. Roughly speaking, an observer classified in the appendices to this report as a casualty, would, without protective clothing probably have become a Casualty Class I according to the system of classification given in Suffield Report No. 47 (See Appendix IV). An observer classified as a "probable casualty" in the appendices to this report would probably have become a Casualty Class II, while of observers classified as "possible casualties", some would probably have become Casualties Class III. (Further, see Addendum to Appendix III).

31. It was not possible by means of military performance tests to extrapolate from the relatively small injuries that were produced by limited exposure through windows in impermeable suits, to the degree of incapacitation which would have been produced had the exposures been made with observers unprotected by impermeable clothing. It was, therefore, impossible to classify the casualties according to the system in C.D. (Australia) Report No. 42.

32. The similarity of the results obtained from Field Experiments 229 and 251, when the thickness of clothing worn by observers differed by one suit of winter-weight woollen underwear, suggests that the wearing of this thickness of clothing has resulted in no marked difference in the extent of lesions produced by low spray with unthickened mustard.

33. There was no apparent difference in the severity of the lesions produced on these trials, whether the observers worked outdoors during the 4-hour period of wearing of their contaminated clothing or rested indoors at 75°F. for this period.

34. The casualty producing power of unthickened mustard appears to be reasonably independent of drop size over the range of sizes encountered on these experiments (0.24 to 0.41 mm. diameter — 0.010 to 0.050 mg. drop weight).

35. Consideration of the results presented in Table IV of Appendix II and Table IV of Appendix III suggests that for wind speeds between 8 mi/hr. and 15 mi/hr., and for drop sizes between 0.24 mm. to 0.41 mm. diameter (0.010 to 0.050 mg.) the back of a man collects approximately 60% of the droplets which would be collected from the same area by an ideal collector.

36. The relatively small loss of mustard from the spray droplets during their fall under the conditions of these experiments, and the large areas contaminated in excess of 2 g/sq.m. indicates that unthickened HS (Levinstein) sprayed from M 10 tanks on A/C flying at low heights would be useful against troops in the open or to contaminate open ground.

CONCLUSIONS*

37. Casualties among troops sprayed with unthickened Levinstein HS in an 8 to 15 mi/hr. wind, at an air temperature of from 60° to 70°F. and wearing respirators, unimpregnated battle dress and cotton shirts will probably be infrequent if the ground contamination density in the vicinity of the individual man is less than 1 g/sq.m. Under similar circumstances it is probable that approximately 50% casualties will result from exposure of troops in regions where the ground contamination is 2 g/sq.m. and that the casualty rate will be high if the ground contamination density exceeds 3 g/sq.m.

38. Of troops wearing respirators, battle dress and cotton shirts, who became contaminated with mustard as a result of exposure to unthickened HS (Levinstein) sprayed from low heights, 50% will probably become casualties if the density of contamination on their clothing is approximately 3 to 4 grams per sq.m. Casualties will probably be high among troops contaminated to an extent much in excess of 4 g/sq.m. and low if the contamination density on their clothing is less than 3 g/sq.m.

39. When men are exposed to unthickened mustard gas spray, (droplets 0.2 to 0.4 mm. diameter) while standing facing downwind in windspeeds of 8 to 15 mi/hr. the density of contamination on their backs will be approximately 60% of the density calculated from the ground contamination in the immediate vicinity of the observers and from the dominant drop size.

40. One M 10 tank, functioned from an A/C flying 50 ft. above ground at a speed of 215 mi/hr will contaminate an area of approximately 20,000 sq. yds. to a density in excess of 2 g/sq.m. when the wind at 2 metres is 8 to 15 mi/hr. Troops wearing respirators, battle dress and cotton shirts exposed within this area stand approximately a 50% chance of becoming casualties as a result of burns through liquid-contaminated clothing.

41. When the air temperature is approximately 65°F., unthickened HS Levinstein sprayed from heights of the order of 50 to 100 ft. will fall to the ground without serious evaporation loss in flight. The overall loss by evaporation before the mustard reaches the ground is likely to be less than 15 percent.

* These conclusions are based on the assumption that troops will wear their clothing for 4 hours after it has been contaminated.

This report was written by Capt. A.W. Birnie of the P.R. Section, Experimental Station, Suffield.

H m Barrett

(E. Ll. Davies)
Chief Superintendent,
Experimental Station.

AWB/SB

APPENDIX I

Field Experiment 229 carried out 25 May 44

MATERIAL

1. (a) One M 10 Smoke Tank charged 326 lbs HS Levinstein dyed 0.5% Dupont Oil Red.

(b) The tank was fitted with a No. 2 detonator at the air inlet and a No. 3 detonator at the discharge outlet.

(c) The viscosity (S.V.) of the charging at 25°C was 5.6 centipoises before dyeing and was 15 centipoises after dyeing.

(d) The specific gravity of the charging was 1,34.

(e) The temperature of the charging at take-off was 13°C.

PROCEDURE

Observers

2. Twenty observers were disposed in lines of five observers each, 60 yards, 80 yards, 100 yards and 120 yards downwind of the upwind edge of the layout. The interval between observers on each line was 100 yards. The first and last observers were situated 300 yards from the crosswind edges of the layout.

3. During the spraying, the observers stood facing downwind. They were dressed as follows:-

Battle-dress, non-impregnated.
Underwear, long-limbed, winter weight, non-impregnated.
Cotton Shirts.
Anklets, socks and boots,
Respirators at the "Gas" position.

(NOTE: In the Canadian Armed Forces it is customary to wear long-limbed underwear from late fall to early spring.)

Impermeable clothing (coat and trousers) were worn over the battle-dress, an impermeable hood over the head and rubber gloves on the hands. The edges of the windows were sewn down to the battle-dress.

4. Windows, 4 in.x 4 in. were cut in the impermeable clothing at the following positions:-

(a) At the back of each shoulder(where the clothing is normally in close contact with the skin).

(b) Over each buttock (where clothing is in close contact with the skin and is pressed against the skin in sitting down).

(c) Over each calf (where the clothing is usually loose over the skin).

5. After the spraying the observers moved off the contaminated area and the impermeable clothing was removed. The remainder of the clothing was worn for four hours after the spraying. During this time ten of the men took part in outdoor Station fatigues, (digging trenches, raking, etc.). The remaining ten men lay or sat about in a warmed (75°F) room.

APPENDIX I (CONTINUED)

Assessment of Ground Contamination

6. Eleven rows of filter paper assemblies, 100 yards between rows, were laid out parallel to the wind direction. Each row was 120 yards long and consisted of filter paper assemblies at 5 yard intervals . The rows were lettered A to L, omitting I, from left to right facing upwind. The papers in each row were numbered 1 to 25 starting at the upwind end. At each observer position four papers were placed on the ground 2½ yards from the observer - one upwind, one downwind, and one to each flank.

Vapor Sampling

7. Two lines of 11 injectors and bubblers,(covered with capes A/C) were set up at 100 yard intervals, one line 80 yards, the other 120 yards from the upwind edge of the layout. Fifteen minute samples were taken during the first hour and subsequently at the end of the second, third and fourth hours.

Analysis of the Spray

8. Samples of the sprayed mustard gas were collected in chloroform in pie plates one of which was placed at each observer position, and 10 yards upwind of each observer position. The amount of dye ineach plate was determined colorimetrically. The amount of mustard gas on each plate was estimated by the bromine titration method. A sample taken from the spray tank before spraying was treated the same way.

Functioning of the M 10 Tank

9. The M 10 Tank was functioned from the starboard wing stowage of a Boston IV A/C. The A/C flew at a height of 55 feet at a true airspeed of 215 mi/hr. The track was 30 yards upwind of the upwind edge of the layout. The M 10 tank was functioned opposite row C.

RESULTS

Meteorological Conditions

10. Time: 1250 M.D.T.
Wind Velocity at time of spraying: 12.5 mi/hr.

	Sampling Periods			
	First Period	Second Period	Third Period	Fourth Period
	1300-1315	1515-1530	1600-1615	1645-1700
Wind Velocity at 2 metres (mi/hr):	15	11	18	14
Measured R:	1.12	1.11	1.13	1.12
Normal R:	1.12	1.11	1.12	1.11
Gustiness: Lateral	.52	.64	.60	.70
Vertical	.29	.31	.33	.32
Air Temperature °C (°F)	19.4 (67.0)	23.1(73.6)	18.0(64.0)	22.7(72.9)
Surface Temp: °C (°F)	26.1(79.0)	30.0(85.0)	20.0(68.0)	27.0(80.0)
Relative Humidity	34%	30%	45%	29%
Temp. Gradient 39 ft - 4 ft °C.	-1.8	-2.2	-1.0	-2.0

APPENDIX I (Cont.)

Ground Contamination

11. The ground contaminations found on the layout filter paper assemblies, and near observer positions are given in Table I at the end of this Appendix. Total recovery on the layout was approximately 45%, though it was noted that there was considerable loss off the downwind edge of the layout. These results were obtained by colorimetric estimation of the dye and take no account of evaporation of mustard from the droplets while in flight.

12. The results of chemical and colorimetric analysis of the spray as caught in the chloroform-filled plates are given in Table II at the end of this Appendix. These results indicate that of the original H content of the charging (0.71 gH/g of original charging) 0.58 gH/gram of the original charging was unevaporated when the spray hit the ground.

Effects on Observers

13. Of the 20 observers exposed to the spray, nine developed vesication on the skin corresponding to the site of the windows in the impermeable clothing they wore. The vesication was usually on the shoulders and buttocks. The effects on the calves were considerably slighter and never exceeded erythema.

14. In spite of the fact that only limited portions of the body were unprotected by impermeable clothing, severe vesication developed in four cases necessitating the admission of these men to hospital. In these four cases extensive vesication involved the buttocks and natal cleft, spreading forwards to the perineum. The scrotum was involved by sharp erythema, swelling and vesication; the penis was markedly swollen and erythematous. In addition the area of vesication on the shoulders extended for an inch or more beyond the site of the windows, and sharp erythema extended in all directions outwards. The severity of these lesions was such that treatment was necessary in hospital for more than three weeks.

15. In the remaining five cases who developed vesication it was considered that the lesions were such that, if impermeable clothing had not been worn, all these men would have become casualties.

16. The lesions on the remaining men were trivial and consisted mainly of erythema. In most cases the reactions on the shoulders and buttocks were of equal intensity, the calves invariably showing milder effects.

17. A summary of the effects on observers together with the relevant data on contamination densities and predominant drop sizes is given in Table III at the end of this Appendix. Descriptions of the lesions produced on this trial are given as an Addendum to this Appendix.

18. It should be pointed out that the densities of ground contamination used in analysing the physiological effects of the spray were the arithmetic means of densities found at four positions 2½ yards from each of the observer positions and that the density in some cases varied considerably between sampling points about the observer position. (See Table I). The position of the filter paper assembly showing the highest density of contamination of the four assemblies placed near each observer appears to be randomly distributed with respect to wind direction.

Vapour Sampling

19. The results of vapour sampling are given in Table IV at the end of this Appendix. The mean (crosswind) concentration found on the 80 yard line was 3.3 mg/cu.m. 15 minutes after the spray had been carried out, and had fallen to 0.88 mg./cu.m. after 4 hours. On the 120 yard line the mean (crosswind) concentration was 1.3 mg/cu.m. at Z plus 15 minutes and had fallen to 0.6 mg/cu.m. after 4 hours.

APPENDIX I (Cont.)

20. Under the conditions of this trial the mean dosage of mustard vapour accumulated along a 1000 yard front, 80 yards downwind of the upwind edge of contamination within the first 4 hours after spraying, was approximately 450 mg. min./cu.m. Similarly the mean dosage accumulated along a 1000 yard front 120 yards downwind of the upwind edge of contamination was approximately 250 mg. min./cu.m.

APPENDIX I (cont)

TABLE I

Ground Contamination (g/sq.m.)

	A	B	C	D	E	F	G	H	J	K	L
1				.067	.21	.0032					
2				.23	.51	.24	.12				
3				1.1	1.5	.66	.60	.0026		.0036	
4				1.7	3.1	1.1	1.1	.10	.017	.0051	
5				2.3	2.9	2.1	.76	.34	.025	.047	
6			.0045	3.3	1.9	3.2	.83	1.2	.0019	.023	
7			.0034	1.8	5.8	1.1	1.9	.018	.053		1.74
8			.0056	3.6	2.3	5.3	1.1	2.3	.035	.043	.013
9			.0026	1.1	3.0	11.	3.4	3.5	.038	.041	.018
10			.010	2.0	1.7	9.9	2.2	.16	.027	1.9	.12
11			.018	1.9	1.5	6.3	2.4	.81	.13	.089	.015
12			.012	1.8	1.3	5.7	2.7	.51	.36	.094	.017
13			.016	3.7 1.4 2.0 0.37	x x 4.0 x	7.7 5.7 4.3 8.5	3.1 4.9 1.4 2.0	.30 .57 .53 .73	.39	.056	.013
14			.016	3.0	2.3	6.4	3.5	.37	.75	.034	.0052
15			.029	2.5	2.3	3.6	2.9	.43	.45	.028	.024
16			.047	2.1	3.7	5.6	4.6	.39	.26	.028	.026
17			.011	2.1 1.4 0.76 .37	x x 4.0 x	2.9 2.7 4.4 4.1	5.9 4.5 2.6 x	.53 .31 0.27 .20	.35	.059	.022
18			.014	2.2	3.9	3.9	3.1	.57	.42	.14	.029
19			.027	1.6	2.3	6.2	1.7	.36	.24	.13	.012
20			.038	1.6	2.9	4.1	.77	.20	.39	.14	.013
21			.094	1.5 .63 1.6 .41	x x 2.4 x	2.6 1.7 7.6 4.0	x 2.6 1.1 .14	.19 .24 0.10 .068	.35	.17	.0070
22			.046	1.4	1.3	4.5	1.3	.048	.36	.26	.016
23			.037	1.4	1.5	9.7	1.3	.050	.33	.19	.024
24			.032	1.1	1.2	1.9	1.6	.032	.17	.13	.027
25			.032	1.7 .54 1.9 .92	7.2 .35 0.40 .43	9.4 3.5 6.3 2.0	1.7 .89 1.2 .24	.040 .079 0.068 .051	.13	.13	.012

Rows A,B,C,D,etc. were 100 yards apart
Lines 1,2,3,etc. were 5 yards apart.
Where no contamination is recorded, ground was uncontaminated.

x = missing
⊙ = observer position.

APPENDIX I (cont)

TABLE II

Estimation of Mustard Content of Spray when it Reached the Ground

Samples of sprayed HSA were collected in chloroform. The figures quoted are the ratios of the amount of M-10 tank charging present as estimated by dye, and the amount of pure H present, as estimated by titration with 10^{-3} Bromine.

The original charging showed an H content of 71 ± 3%. The sprayed product, as it reached theground, showed an average H content of 58± 3% in terms of the original charging. Detailed results aregiven below.

Position	H/ml $CHOl_3$(ByBr) charging/ml $CHOl_3$(by dye)	Position	H/ml $CHOl_3$ (By Br) charging ml/$CHCl_3$(by dye)
D 11	0.60	F 11	0.66
13	0.56	13	0.60
15	0.53	15	0.62
17	0.60	17	0.61
19	0.69	19	0.61
21	0.69	21	—
23	0.73	23	0.39
D 25	0.72	F 25	0.72
Av.	0.64	Av.	0.60
F 11	0.62	G 11	0.74
13	0.61	13	0.64
15	0.59	15	0.48
17	0.48	17	0.70
19	0.47	19	0.60
21	0.45	21	0.65
23	0.47	23	0.61
E 25	0.46	G 25	0.69
Av.	0.52	Av.	0.64
		H 11	0.69
		13	0.48
		15	0.40
		17	0.48
		19	0.47
		21	0.55
		23	0.52
		H 25	0.44
		Av.	0.50

Overall Average Ratio = 0.58

APPENDIX I (CONTINUED)

TABLE III

Contamination Density/Drop Size Data

OBSERVER	CONTAMINATION DENSITY** (g/sq.m.)	DROP SIZE (mm.)	(mg.)	TYPE OF LESION PRODUCED	PROBABLE CASUALTY OR NON-CASUALTY
* 13F	6.6	0.55	0.12	V	Casualty
25F	5.3	0.4	0.045	V	"
* 17G	4.3	0.35	0.032	V	"
17E	4.0	0.4	0.045	V	"
* 13E	4.0	0.4	0.045	V	"
21F	4.0	0.045	0.065	V	"
* 17F	3.5	0.45	0.065	V	"
* 13G	2.8	0.45	0.065	V	"
* 21E	2.4	0.35	0.032	E	Non-Casualty
13D	1.9	0.35	0.032	V	Casualty
21G	1.3	0.2	0.006	E -	Non-Casualty
25D	1.2	0.2	0.006	E	Non-Casualty
* 17D	1.2	0.35	0.032	E +	"
25G	1.0	0.2	0.006	E	"
21D	1.0	0.2	0.006	E	"
13H	0.53	0.2	0.006	E -	"
* 25E	0.49	0.3	0.02	E	"
* 17H	0.33	0.35	0.032	E -	"
* 21H	0.15	0.35	0.032	E -	"
25H	0.06	0.35	0.032	E -	"

* - During the wearing period of 4 hours after the spray, these men were engaged in working in the open, (digging trenches, raking, etc.).

** - The contamination density given here is the mean of the ground contamination densities recorded on filter paper assemblies placed on the ground at four positions 2½ yards from each observer. (See Appendix I).

In the above table the classification of casualty or non-casualty is based on the effects which would be expected if impermeable clothing had not been worn. It may be noted however that observers 25F, 17G, 13E and 13D became casualties requiring admission to hospital in spite of being protected by impermeable clothing except for windows as described in the body of this report.

ADDENDUM TO APPENDIX I

DESCRIPTION OF LESIONS PRODUCED BY LOW SPRAY OF UNTHICKENED MUSTARD GAS

(Note: It should be borne in mind that during the spray the observers, whose lesions are described below, wore impermeable clothing. A window, 4" x 4", was cut out of the impermeable clothing over each shoulder, over each buttock, and over each calf exposing the clothing beneath. The impermeable clothing was sewn down at the edges to the Battle Dress so that no liquid agent could flow down between the outer impermeable clothing and the Battle Dress. (The classification of casualty or non-casualty is based on the effects which would be expected if impermeable clothing were not worn.)

* During the wearing period of 4 hours after the spray, these men were engaged in working in the open, (digging trenches, raking etc.). The remaining men lay or sat in a warmed room (75°F.) for 4 hours.

* OBSERVER 13F

Contamination Density 6.6 g/sq.m.; Drop Size 0.55 mm. (0.12 mg.). Twenty-four hours after the spray the left shoulder showed intense vesication and the right shoulder erythema. After 48 hours the right shoulder had developed pinpoint vesication. (See Plate I.)

Casualty

* OBSERVER 17G

Contamination Density 4.3 g/sq.m.; Drop Size 0.35 mm. (0.032 mg.). Twenty-four hours after the spray both shoulders were vesicated. Erythema extended from both vesicated sites downwards between the shoulderblades to the waist. The buttocks showed intense erythema which at 48 hours had proceeded to vesication at the upper part of the natal cleft. The calves never developed more than a mild erythema. On the 4th day after the spray the scrotum showed intense erythema with areas of excoriation. The penis was slightly swollen. (See Plate II).

Casualty.

OBSERVER 25F

Contamination Density 5.3 g/sq.m.; Drop Size 0.4 mm. (0.045 mg.). Twenty-four hours after the spray both shoulders showed areas of intense vesication. Erythema extended from the nape of the neck to the waist. The buttocks were involved by vesication which extended far beyond the areas exposed by the windows. Vesication involved the entire natal cleft. By the 2nd day the vesication had spread forwards to involve the perineum. The scrotum was intensely inflamed and swollen and numerous small blisters were scattered over it. The penis was swollen with small areas of excoriation due to minute broken blisters. The left leg showed an area of erythema which by 48 hours had proceeded to vesication. On the 4th day after the spray this man was very distressed, the vesication on the buttocks and perineum having continued to develop. Even after application of different types of treatment to the lesions, he complained of incessant pain and irritation, particularly of the scrotum and penis. The temperature reached 102°F. The glands in the groins became swollen and tender and insomnia was marked. On the 5th day the condition had improved and irritation was less marked. By this time the lesions had apparently reached their full maturity. When considering the severity of the lesions produced on this observer, it should be borne in mind that only windows, 4" x 4", were cut

ADDENDUM TO APPENDIX I (CONTD.)

OBSERVER 25F (cont.)

in his impermeable clothing. If no protection had existed, it may be assumed that the severity of the lesions would have been considerably greater. (See Plates III & IV.)

OBSERVER 17E

Contamination Density 4.0 g/sq.m.; Drop Size 0.4 mm. (0.045 mg.). Twenty-four hours after the spray erythema was present on both shoulders, a mild erythema on both buttocks and no reaction had developed on the calves. On the 2nd day after the spray there were areas of pinpoint vesication on both shoulders. On the following day these areas of pinpoint vesication on the shoulders had progressed to true vesication. Neither the buttocks nor the legs showed significant lesions at any time.

Casualty.

* OBSERVER 13E

Contamination Density 4.0 g/sq.m.; Drop Size 0.4 mm. (0.045 mg.). Twenty-four hours after the spray both shoulders showed vesicated areas which continued to increase in size and intensity during the second day. Severe vesication developed on the buttocks chiefly over the site of the windows and extending to the upper part of the natal cleft. These lesions also continued to increase in severity until the second or third day after the spray. On the second day mild erythema developed on the penis and scrotum. The calves showed a mild erythema. (See Plates V and VI).

Casualty.

OBSERVER 21F

Contamination Density 4.0 g/sq.m.; Drop Size 0.45 mm. (0.065 mg.). Twenty-four hours after the spray both shoulders showed areas of pinpoint vesication. The buttocks showed diffuse erythema and the calves a slight degree of erythema. By the 48th hour both shoulders were vesicated, the erythema on the buttocks more intense, with vesication on the upper part of the natal cleft.

Casualty.

* OBSERVER 17F

Contamination Density 3.5 g/sq.m.; Drop Size 0.45 mm. (0.065 mg.). Twenty-four hours after the spray, both shoulders were involved by pinpoint vesication and both buttocks and calves by erythema. Forty-eight hours after the spray, vesication appeared on buttocks and in the natal cleft.

Casualty.

* OBSERVER 13G

Contamination Density 2.8 g/sq.m.; Drop Size 0.45 mm. (0.065 mg.). Twenty-four hours after the spray both shoulders showed areas of pinpoint vesication. There was no reaction on buttocks or calves. By the third day the left shoulder was vesicated and the right shoulder showed an intense erythema which did not progress to vesication. No effects appeared on the buttocks or calves.

Casualty.

ADDENDUM TO APPENDIX I (CONTD.)

OBSERVER 21E

Contamination Density 2.4 g/sq.m.; Drop Size 0.35 mm. (0.032 mg.). Twenty-four hours after the spray both shoulders were involved by erythema. The buttocks were erythematous. The calves showed no reaction. Over the succeeding few days these lesions showed no appreciable increase in intensity. Since only six small circumscribed areas of uncovered battle dress were exposed to the spray, it is difficult to say in the case of observers contaminated to densities of this order whether or not the lesions would be of casualty severity if the impermeable clothing had not been worn. Until the question is settled by further observation, these men are classified as non-casualties with the reservation that a number of them may become casualties after an interval of 5 to 10 days or later.

Non-casualty.

OBSERVER 13D

Contamination Density 1.9 g/sq.m.; Drop Size 0.35 mm. (0.032 mg.). Twenty-four hours after the spray the left shoulder was vesicated. The right shoulder showed pinpoint vesication. Erythema involved both buttocks and a mild erythema had developed on both calves. Forty-eight hours after the spray the vesication on the shoulders had increased in intensity. Vesication had appeared at the top of the natal cleft. The scrotum and penis were involved by a sharp erythema. Four days after the spray the penis and scrotum were still severely inflamed with small areas of excoriation and exudation on the scrotum.

Casualty.

OBSERVER 25D

Contamination Density 1.2 g/sq.m.; Drop Size 0.2 mm. (0.006 mg.). Twenty-four hours after the spray both shoulders and buttocks showed a mild erythema. Mild erythema also involved the penis and scrotum. Over the succeeding days these lesions did not increase in intensity.

Non-casualty.

OBSERVER 21G

Contamination Density 1.3 g/sq.m.; Drop Size .2 mm. (0.006 mg.). Twenty-four hours after the spray a mild erythema had developed on the shoulders. No effects were produced on the buttocks or calves. Over the succeeding days no change in the lesions developed.

Non-casualty.

OBSERVER 25G

Contamination Density 1.0 g/sq.m.; Drop Size 0.2 mm. (0.006 mg.). Twenty-four hours after the spray a mild erythema had developed on the shoulders. The buttocks were involved by a slightly more intense erythema. No effects were produced on the calves. Over the succeeding days these lesions did not develop any further.

Non-casualty.

OBSERVER 21D

Contamination Density 1.0 g/sq.m.; Drop Size 0.2 mm. (0.006 mg.). The lesions produced on this observer were confined to areas of mild erythema on the shoulders, back and calves.

Non-casualty.

ADDENDUM TO APPENDIX I (CONTD.)

* OBSERVER 17D

Contamination Density 1.2 g/sq.m.; Drop Size 0.35 mm. (0.032 mg.). Twenty-four hours after the spray a mild erythema had developed on the shoulders, back and calves. Forty-eight hours after the spray the lesions on the shoulders and back had developed in intensity but did not progress to vesication. Slight erythema accompanied by itching of the scrotum and penis had developed.

Non-casualty.

OBSERVER 13H

Contamination Density 0.53 g/sq.m.; Drop Size 0.2 mm. (0.006 mg.). Beyond a mild degree of erythema on the buttocks this observer developed no effects.

Non-casualty.

* OBSERVER 25E

Contamination Density 0.49 g/sq.m.; Drop Size 0.3 mm. (0.02 mg.). This observer developed a mild erythema on the shoulders, back and calves. The lesions did not increase in intensity.

Non-casualty.

*OBSERVER 17H

Contamination Density 0.33 g/sq.m.; Drop Size 0.35 mm. (0.032 mg.). The only effects produced on this observer were two areas of mild erythema on the shoulders.

Non-casualty.

*OBSERVER 21H

Contamination Density 0.15 g/sq.m.; Drop Size 0.35 mm. (0.032 mg.). Beyond a mild erythema on the shoulders this man displayed no effects.

Non- casualty

OBSERVER 25H

Contamination Density 0.06 g/sq.m.; Drop Size 0.35 mm. (0.032 mg.). A mild erythema developed on both shoulders. No effects were produced on the buttocks or calves.

Non-casualty.

APPENDIX II

Field Experiment No. 241 carried out 15 June 44

MATERIAL

1. (a) One MIO tank charged 326 lbs HS (Lavinstein) dyed 0.5% Dupont Oil Red.

(b) The tank was fitted with a No. 2 detonator at the air inlet and a No. 3 detonator at the discharge outlet.

(c) The viscosity (Ostwald) of the charging at 25°C was 5.6 centipoises before dyeing and 15 centipoises after dyeing.

(d) The specific gravity of the charging was 1.34.

(e) The temperature of the charging at take-off was 17°C.

PROCEDURE

Observers

2. Twenty-eight observers were disposed in lines of seven observers each, 100 yards, 120 yards, 140 yards, and 160 yards downwind of the upwind edge of the layout. The observers were 100 yards apart in each line. The end observers in each line were 200 yards from the crosswind edges of the layout.

3. During the spraying the observers stood facing downwind. They were dressed as follows:

Battle-dress, non-impregnated.
Shirts, long-sleeved, cotton.
Anklets, socks and boots.
Respirators at the "Gas" position.
Impermeable clothing (coat and trousers) was worn over the battle-dress; impermeable hoods were worn over the head, and rubber gloves on the hands.
No underwear was worn by the observers.

4. Windows 4" x 4" were cut in the impermeable clothing in the following positions:

(i) One window at the back of each shoulder.

(ii) One window in the centre of the back, just above the belt, on the loosely fitting part of the battle dress blouse. The edges of the windows were sewn down to the battle dress.

5. A filter paper assembly (with circular filter paper surface 8 inches in diameter) was fastened to the back of each observer just below the waist line.

6. After the spray had fallen the observers moved off the contaminated area and the impermeable clothing was removed. The remainder of the clothing was worn for four hours after the spraying. During this time fourteen of the men took part in outdoor Station fatigues (digging trenches, raking, etc.). The remaining fourteen men lay or sat about in a room at 75°F.

APPENDIX II

ASSESSMENT OF GROUND CONTAMINATION

7. Eleven rows of filter paper assemblies, 100 yards between rows, were laid out parallel to the wind direction. Each row was 160 yards long and consisted of filter paper assemblies at 20-yard intervals. The rows were lettered "A" to "L" from left to right facing upwind. The papers in each row were numbers from 1 to 9 starting at the upwind end. At each observer position 4 filter papers were placed on the ground 2½ yards from the observer, one upwind, one downwind, and one to each flank. Assessment of ground contamination was carried out by colorimetric estimation of the dye caught on the filter papers.

8. The M10 tank was functioned from the starboard wing stowage of a Boston IV (A20J) aircraft. The A/C flew at a height of 35 feet (measured by theodolites) at a true air speed of 215 mi/hr. The track was 30 yards upwind of the upwind edge of the layout. The M10 tank was functioned opposite Row B.

RESULTS

Meteorological Conditions

9.
Time: 1136 M.D.T.
Wind velocity at 2 metres at time of spraying: 15 mi/hr.
Air temperature: 16°C. (61.5°F).
Ground temperature: 21°C. (70°F.).
Relative humidity: 67%
Temp. gradient: 39 ft. - 4 ft.: - 1.8°C.

Contamination Densities:

10. The contamination densities found on the layout and on the filter paper assemblies fastened to the backs of observers are given in Tables I and II at the end of this Appendix.

Effects on Observers

11. Of the 28 observers exposed to the spray only two developed vesication of the skin. The vesication was on the shoulders corresponding to the site of the windows in the impermeable clothing they wore. No vesication was noted on the region of the window on the lower back. It was considered that these men would have become casualties had they not worn impermeable clothing.

12. Besides the two mentioned above, five observers showed areas of erythema and oedema (E +). Three of these men had been on previous trials where they had been burned by H under hot humid conditions. An additional two men, of which one had been previously burned by H vapour under hot humid conditions, showed sharp erythema (E); five men showed faint erythema (E -). Of these latter five, one had previously been burned by H vapour under hot humid conditions.

13. A summary of the physiological effects on observers together with the contamination densities found on observers and on the ground at observer positions is given in Table III at the end of this Appendix. Descriptions of the lesions obtained on this trial are given at the end of this Appendix.

14. Due to the low height at which the A/C flew, the heaviest contamination was deposited well upwind of the observers with the result that the contamination densities obtained at observer positions were lighter than were expected. The number of observers showing even mild lesions was therefore small.

APPENDIX II (cont)

15. The vertical contamination densities obtained on the backs of observers may be compared with those which would be expected, knowing the ground contamination density, windspeed, and size of droplets involved. The results of such a comparison are given in Table IV at the end of this Appendix.

16. The geometric mean ratio of calculated to observed vertical contamination density is 1.6. The vertical contamination density was calculated from the horizontal density assuming that the surface of a man's back is an ideal collector and that the wind direction was normal to the man's back. In actual practice this will not be the case, so that it is to be expected that the ratio would be greater than unity.

17. The wide variation of the ratio from man to man probably reflects the deviation of the measured ground contamination from that which corresponded to the contamination measured on the observer's back, i.e., on account of the patchiness of contamination and the low angle of descent of the drops, the ground contamination at an observer's feet would not be the same as the ground contamination which would normally be produced by the droplets striking the observer.

APPENDIX II

The contamination densities found on the layout and on the backs of observers, together with dominant drop size at each point are given in Table I. The individual densities found on the four papers at observer positions are given in Table II.

Table I

Position	Contamination (g/sq.m.) Layout (mean)	Back of Observer	Dominant Drop size (mg) Layout	Observer
B 1	0.02			
2	0.07			
3	0.21			
4	0.09			
5	0.04			
6	0.02			
7	0.08			
8	0.22			
9	0.34			
C 1	2.0			
2	4.0			
3	1.08			
4	0.46			
5	0.61			
6	0.18	0.43	.005	.025
7	0.11	0.13	.015	.015
8	0.10	0.18	.015	.020
9	0.07	0.19	.010	.010
D 1	1.05			
2	8.8			
3	7.7			
4	5.8			
5	3.2			
6	1.23	7.3	-	.015
7	0.90	2.5	-	.050
8	0.95	-	-	.025
9	0.97	4.9	.025	.035
E 1	8.3			
2	4.2			
3	1.72			
4	2.0			
J 1	0.10			
2	0.08			
3	0.01			
4	0.02			
5	0.01			
6	0.04	0.076	.010	.010
7	0.03	0.090	.010	.010
8	0.02	0.11	.010	.015
9	0.03	0.08	.015	.015
K 1	0.01			
2	0.04			
3	0.03			
4	0.05			
5	0.03			
6	0.02			
7	0.05			
8	0.02			
9	0.03			

Position	Contamination (g/sq.m.) Layout (mean)	Back of Observer	Dominant Drop size (mg) Layout	Observer
E 5	2.5			
6	0.51	0.85	025	.015
7	0.74	6.4	-	.025
8	0.68	2.9	.020	.025
9	0.07	0.10	.020	.005
F 1	0.90			
2	2.6			
3	5.7			
4	4.0			
5	1.06			
6	0.56	1.94	-	.020
7	0.42	0.98	-	.020
8	0.29	0.28	.010	.015
9	0.81	2.2	-	.005
G 1	0.40			
2	0.91			
3	0.28			
4	0.66			
5	0.16			
6	0.18	0.26	.015	.025
7	0.11	0.47	-	.010
8	0.05	0.30	.015	.020
9	0.04	0.10	.010	.005
H 1	0.03			
2	0.34			
3	0.10			
4	0.14			
5	0.08			
6	0.07	0.28	.005	.005
7	0.11	1.18	.005	.010
8	0.03	0.09	.010	.015
9	0.05	0.09	.010	.020
L 1	<0.01			
2	0.01			
3	0.06			
4	0.01			
5	0.02			
6	0.01			
7	0.01			
8	0.01			
9	<0.01			

TABLE II

Contamination Density in grams per square metre.

Position	Layout paper observers left	(b) observers right	(c) downwind (front)	(d) upwind (rear)	Mean
C 6	0.41	0.12	0.04	0.16	0.18
7	0.27	0.08	0.02	0.06	0.11
8	0.10	0.08	0.04	0.19	0.10
9	0.08	0.12	0.03	0.05	0.07
D 6	1.12	0.93	0.88	2.01	1.23
7	0.58	1.59	0.52	0.92	0.90
8	0.97	1.09	0.85	0.89	0.95
9	1.74	0.21	0.83	1.11	0.97
E 6	1.04	0.52	0.18	0.40	0.51
7	0.86	0.67	0.58	0.85	0.74
8	0.53	1.45	0.12	0.64	0.68
9	0.05	0.08	0.05	0.08	0.07
F 6	0.40	0.97	0.50	0.35	0.56
7	0.85	0.16	0.41	0.25	0.42
8	0.21	0.24	0.08	0.61	0.29
9	0.60	0.77	0.60	1.25	0.81
G 6	0.37	0.12	0.14	0.10	0.18
7	0.11	0.08	0.18	0.06	0.11
8	0.04	0.04	0.05	0.06	0.05
9	0.06	0.04	0.04	0.02	0.04
H 6	0.15	0.04	0.05	0.05	0.07
7	0.04	0.04	0.25	0.12	0.11
8	0.04	0.02	0.02	0.03	0.03
9	0.04	0.05	0.06	0.06	0.05
J 6	0.05	0.02	0.03	0.05	0.04
7	0.05	0.03	0.02	0.04	0.03
8	0.02	0.01	0.01	0.04	0.02
9	0.05	0.01	0.02	0.02	0.03

A

TABLE III

W Observer Position	Ground Contamination Density g/sq.m.	Vertical Contamination Density (Observer's backs) g/sq.m.	Dominant Drop Size found on Observers		Physiological Effect	Probable Casualties*
			mg	mm		
W D6	1.23	7.3	.015	0.28	V, E +	Yes
W D9	0.97	4.9	.035	.37	S E	No
W D8	0.95	-	.025	.33	S E +	possible (Yes)
W D7	0.90	2.5	.050	.41	E +	No
F9	0.81	2.2	.005	.19	S E +	No
W E7	0.74	6.4	.025	.33	V, E +	Yes
W E8	0.68	2.9	.025	.33	S E +	(No)
W F6	0.56	1.94	.020	.30	E +	No
W E6	0.51	0.85	.025	.33	E -	No
W F7	0.42	0.98	.020	.30	E	No
F8	0.29	0.28	.015	.28	Nil	No
W C6	0.18	0.43	.025	.33	Nil	No
G6	0.18	0.26	.025	.33	Nil	No
W C7	0.11	0.13	.015	.28	Nil	No
G7	0.11	0.47	.010	.24	Nil	No
H7	0.11	1.18	.010	.24	E -	No
W G8	0.10	0.18	.020	.30	Nil	No
A6	0.07	0.28	.005	.19	Nil	No
W E9	0.07	0.10	.005	.19	E -	No
W C9	0.07	0.19	.010	.24	Nil	No
G8	0.05	0.30	.020	.30	Nil	No
H9	0.05	0.09	.015	.28	Nil	No
G9	0.04	0.10	.005	.19	S E -	No
J6	0.04	0.08	.010	.24	Nil	No
H8	0.03	0.09	.015	.28	E -	No
J7	0.03	0.09	.010	.24	Nil	No
J8	0.02	0.11	.015	.28	Nil	No
J9	0.03	0.08	.015	.28	Nil	No

*In the above table the classification of casualty or non-casualty is based on the effects which would be expected if impermeable clothing had not been worn.

S These men had been previously burned by H vapour under hot humid conditions.

W These men worked on outdoor fatigues for 4 hours after the trial.

APPENDIX II

TABLE IV

Observer	Vertical contamination density		Ratio
	Calculated	Observed	Calculated / Observed
D6	5.7	7.3	0.78
D9	3.4	4.9	0.69
D8	3.9	-	-
D7	2.9	2.5	1.16
F9	5.2	2.2	2.36
E7	3.0	6.4	0.47
E8	2.7	2.9	0.93
F6	2.4	1.94	1.24
E6	2.0	0.85	2.35
F7	1.8	0.98	1.84
F8	1.3	0.28	4.65
C6	.71	0.43	1.65
G6	.71	0.26	2.74
C7	.50	0.13	3.85
G7	.59	0.47	1.25
H7	.59	1.18	0.50
C8	.43	0.18	2.40
H6	.44	0.28	1.57
E9	.44	0.10	4.40
C9	.38	0.19	2.00
G8	.22	0.30	0.73
H9	.23	0.09	2.56
G9	.26	0.10	2.60
J6	.21	0.076	2.76
H8	.14	0.090	1.55
J7	.17	0.090	1.89
J8	.09	0.110	0.82
J9	.14	0.08	1.75
	Geometric Mean		1.60

ADDENDUM TO APPENDIX II

Casualty Producing Power of Unthickened Mustard Sprayed from Low Altitudes under Temperate Conditions

Note. It should be remembered that during the spray the observers wore impermeable clothes. A window, 4" x 4" was cut out of the impermeable clothing over each shoulder and the middle of the back. The impermeable clothing was sewn to the battle dress at the edges of the windows to prevent ~~mustard~~ liquid flowing down between the two layers of cloth.

Casualties and non-casualties are based on the effects to be expected if impermeable clothes had not been worn.

Observer C 8 Contamination on observer 0.43 gms/m^2. Predominant drop size .025 mg. Contamination on ground 0.18 gms/m^2. No effects. Non-casualty.

Observer C 7 Contamination on observer 0.13 gms/m^2. Predominant drop size .015 mg. Contamination on the ground 0.11 gms/m^2. No effects. Non-casualty.

Observer C 8 Contamination on observer 0.18 gms/m^2 Predominant drop size .020 mg. Contamination on ground 0.10 gms/m^2. No effects. Non-casualty.

Observer C 9 Contamination on observer 0.19 gms/sq m. Predominant drop size .010 mg. Contamination on ground 0.07 gms/m^2. No effects. Non-casualty.

Observer D 6 Contamination on observer 7.3 gms/m^2. Predominant drop size .015 mg. Contamination on ground 1.23 gms/m^2. Twenty-four hours after the spray, both shoulders showed vesicated areas surrounded by pin point vesication. The entire back was involved in erythema from the neck to the belt line. Casualty.

Observer D 7 Contamination on observer 2.5 g/ sq m. Predominant drop size 0.050 mg. Contamination on ground 0.90 g/sq m. By 24 hours this man had developed wide spread erythema of the back with no oedema. This remained up to 72 hours and then started to fade. Non-casualty.

Observer D 8 Contamination on the ground in this region was 0.95 gms/m^2. The card from the back of the observer was lost. The predominant drop size was .025 mg. At 24 hours this observer showed erythema and oedema at the site of the windows on his shoulders and a morbilliform rash involving the back and extending down over the buttocks. The rash was also apparent at the bends of the elbows and in the groin. At 72 hours the rash had appeared in both armpits and an area was desquamating on each shoulder.

This man had previously sustained a burn around his neck from H vapour under hot humid conditions. Under the conditions of this trial he might possibly have been a casualty, but whether from the spray or combined actions of sensitivity and spray it is hard to say.

Possible Casualty.

ADDENDUM TO APPENDIX II

Observer D 9 Contamination on the observer was 4.9 gms/m^2. Ground contamination was 0.97 gms/m^2. The predominant drop size was .035 mg. This man at 24 hours showed extensive erythema on his shoulders which had progressed by 48 hours and showed a morbilliform type ofrash. This man had also been exposed on a previous trial to mustard vapour under hot humid conditions. Non-Casualty.

E 6 Contamination on the observer was 0.85 gms/m^2; ground contamination was 0.51 gms/m^2; the predominant drop size was .015 mg. At 24 hours he showed a small area of faint erythema on his left shoulder which had started to fade at 48 hours. Non-Casualty.

E 7 Contamination on this observer was 6.4 gms/m^2. Ground contamination was 0.74 gms/m^2. The predominant drop size was .025 mg.

At 24 hours this man showed small annular vesicles on both shoulders surrounded by areas of erythema and oedema. There was some erythema in the small of the back in the region of the third window.

At 48 hours the vesication had progressed and the areas of erythema and oedema had become larger. Casualty.

E 8 Contamination on this observer was 2.9 gms/m^2 by drops .025 mg. in size. Ground contamination was 0.68 gms/m^2.

At 24 hours he showed areas of erythema and oedema in the region of the windows on his shoulders. These two areas were surrounded by a morbilliform type of rash. This man had been previously burned by H vapour under hot humid weather conditions.

It is doubtful if this man would have become a casualty under the conditions of this trial.

~~Possible~~ Non-Casualty

ADDENDUM TO APPENDIX II

Observer

E 9 Contamination on this observer was 0.10 gms/m^2 by droplets of .005 mg. size. Ground contamination was 0.07 gms/m^2. At 24 hours he showed a faint area of erythema on his left shoulder which faded by 48 hours.

Non-Casualty

F 6 Contamination on this observer was 1.94 gms/m^2 by drops of .020 mg. Ground contamination was 0.56 gms/m^2. At 24 hours he showed erythema and oedema of skin over the shoulders and faint erythema of the mid-line of the back. This area progressed in erythema to 48 hours but never desquamated.

Non-Casualty

F 7 Contamination on this observer was 0.98 gms/m^2 by droplets of .020 mg. Ground contamination was 0.42 gms/m^2. At 24 hours he showed a diffuse area of erythema over the upper back. At 48 hours these areas had become better defined and more localized to the areas underneath the windows.

Non-Casualty

F 8 Contamination on this observer was 0.28 g/sq. m. The predominant drop size was .015 mg. Ground contamination was 0.29 g/sq. m. No effects.

Non-Casualty

F 9 The contamination on this observer was 2.2 gms/m^2 by drops of .005 mg. size. Ground contamination was 0.81 gms/m^2. At 24 hours there were areas of erythema and oedema present on the shoulders. By 48 hours a morbilliform rash had developed which extended from the neck to the buttocks. This man had been previously burned by H vapor under hot, humid conditions. Under the conditions of this trial it is unlikely that he would have become a casualty.

Non-Casualty

G 6 The contamination on this observer was 0.26 g/sq. m. The predominant drop size was .025 mg. Ground contamination was 0.18 g/sq. m. No lesions developed.

Non-Casualty

G 7 The contamination on the observer was 0.47 gms/m^2 by drops of .07 mg. size. Ground contamination was 0.11 gms/m^2. No lesions developed.

Non-Casualty

G 8 The contamination on the observer was 0.30 gms/m^2 by drops of .020 mg. size. Ground contamination was 0.05 gms/m^2. No lesions developed.

Non-Casualty

G 9 The contamination on this observer was 0.10 gms/m^2 by drops of .005 mg. size. Ground contamination was 0.04 gms/m^2. At 24 hours a morbilliform rash had appeared in the mid-line of the back, extending from the neck to the natal cleft. This man had previously been exposed to H vapor under hot humid conditions.

Non-Casualty

H 6 The contamination on the observer was 0.28 gms/m^2 by drops of .005 mg. size. Ground contamination was 0.07 gms/m^2. No lesions developed.

Non-Casualty

ADDENDUM TO APPENDIX II

Observer

H 7 The contamination on the observer was 1.18 gms/m^2 by drops of .010 mg. size. Ground contamination was 0.11 gms/m^2. At 24 hours the entire upper back was involved in a faint area of erythema which faded by 72 hours.

Non-Casualty

H 8 The contamination on the observer was 0.09 g/sq. m. The predominant drop size was .015 mg. Ground contamination was 0.03 g/sq. m. At 24 hours there was an area of faint erythema in the middle of the upper part of the back. This had faded by 72 hours.

Non-Casualty

H 9 The contamination on the observer was 0.09 g/sq. m. The predominant drop size was .020 mg. Ground contamination was 0.05 g/sq. m. No lesions developed.

Non-Casualty

J 6 The contamination on the observer was 0.076 gms/m^2 by drops of .01 mg. size. Ground contamination was 0.04 gms/m^2. No lesions developed.

Non-Casualty

J 7 The contamination on the observer was 0.090 gms/m^2 by drops of .01 mg. size. Ground contamination was 0.03 gms/m^2. No lesions developed.

Non-Casualty

J 8 The contamination of the observer was 0.11 gms/m^2 by drops of .015 mg. size. Ground contamination was 0.02 gms/m^2. No lesions developed.

Non-Casualty

J 9 The contamination on the observer was 0.08 gms/m^2 by drops of .01g mg. size. The ground contamination was 0.03 gms/m^2. No lesions developed.

Non-Casualty

APPENDIX III

Field Experiment 251 Carried out 8 August

MATERIAL:

1.
(i) One M10 Tank charged 326 lbs. HS (Levenstein) dyed 1.0 % Williams Red dye. The charging was filtered before use.

(ii) The tank was fitted with a No. 2 detonator at the air inlet and a No. 3 detonator at the discharge outlet.

(iii) The viscosity (Ostwald) of the charging at 25°C was 5.1 centipoises before and after dyeing.

(iv) The Specific gravity of the charging at 10°C was 1.34.

(v) Temperature of the charging at take off was 16°C.

PROCEDURE:

Observers

2. Thirty - five observers were disposed in five lines of seven observers each, the lines being 60, 80, 90, 100 and 120 yards downwind of the upwind edge of the layout. The interval between observers in each line was 50 yards for the central five observers and 100 yards for the two end observers. The end observers of each line were situated 200 yards from the cross - wind edges of the layout.

3. During the spraying the observers stood facing downwind. They were dressed as follows:

Battle-dress non-impregnated.
Shirts, long sleeved cotton.
Anklets socks and boots.
Respirators at the gas position.

Impermeable clothing (coat and trousers) was worn over the battle-dress, impermeable hoods were worn over the head, and rubber gloves on the hands. No underwear was worn by the observers.

4. Windows 4" x 4" were cut in the impermeable clothing in the position listed below:-

(i) One window at the back of each shoulder.
(ii) One window at the centre of the back just above the belt on the loose fitting part of the battle-dress blouse.
(iii) One window in the area of each collar bone in front. (Trials at Dugway have shown that there is a certain amount of contamination deposited on the downwind surface of the observers.)

The edges of the windows were sewn down to the underlying battle-dress.

5. A filter paper assembly fitted with a cardboard stiffener was fastened to the back of each observer just below the waist line so that it hung in a vertical plane.

6. After the spray had fallen the observers moved off the contaminated area and the impermeable clothing was removed. The remainder of the clothing was worn for four hours after the spraying. During this time 15 of the men took part in outdoor station fatigues (shovelling gravel). The remaining 20 men sat or lay about in a room at 75°F.

Appendix III (cont.)

Assessment of Ground Contamination

7. Twenty-one rows of filter paper assemblies, 50 yards between rows, were laid out parallel to wind direction. The rows were lettered A to V; omitting I, from left to right facing upwind. In each row the papers were numbered from 1 to 41 starting at the upwind end. Each row was 250 yards long and consisted of filter paper assemblies at 5 yard intervals for the first 150 yards downwind, and at 10 yard intervals for the remaining 100 yards. At each observer position, 4 filter paper assemblies were placed on the ground at the corners of a 3 yard square. The observer was stationed a distance D from the centre of the square, given in yards by the formula:-

$$D \text{ (yards)} = \frac{\text{windspeed at 1 metre in mi/hr.}}{4}$$

(Drops 0.35 mm. in diameter will travel this distance downwind in falling from a height of 3 ft. the height of the filter paper attached to the observer.)

8. At each observer position and at all filter paper assembly points on Row E a piece of photographic paper 2" x 1" was placed in the ground to obtain a sample of the contamination for drop size analysis by the method outlined in Suffield Technical Minute No. 9 in case the contamination on the filter papers was too heavy for stain-size measurements.

9. Samples of the sprayed mustard gas were collected in chloroform in pie plates one of which was placed at each of positions 9, 13, 17, 21 and 29 of rows G, J, and L. The amount of dye in each plate was determined colorimetrically. The amount of mustard gas on each plate was estimated by the bromine titration method. A sample of charging from the spray tank was similarly analysed for dye and mustard content.

10. The M 10 tank was functioned from the starboard wing stowage of a Boston IV (A 20 J) aircraft. The aircraft flew at a height of 50 feet, (measured by theodolites) at a true air speed of 225 mi/hr. The track was 30 yds. upwind of the edge of the layout. The M 10 tank was functioned opposite row G.

RESULTS:

Meteorological Conditions

11. Time: 0832 hours. M.D.T.
Wind velocity at 2 metres at time of spraying 8.4 mi/hr.
Air temperature 17°C (62°F).
Ground temperature 20°C (68°F).
Relative Humidity 61 %.
Temperature gradient 39 ft. to 4 ft. -1.2°C to -2.0°C.

Contamination Densities

12. The contamination densities found by extraction and colorimetric estimation of the dye caught on filter paper assemblies on the layout at observer positions and on the backs of observers are given in Table III at the end of this appendix. The contamination of the layout is summarized in Table I below:

Appendix III (cont.)

TABLE I

Summary of Contamination found on layout.

Density Range (g/sq.m.)	Area Contaminated (sq.yds.)	Mean Density (g/sq.m.)	Recovery, percent of weapon contents.
10 to 50	1000	22	12.6
5.0 to 10	3000	7.0	11.9
1.0 to 5.0	35800	2.2	45
0.50 to 1.0	22500	0.72	9.2
0.10 to 0.50	68000	0.24	8.9
> 0.10	97400	0.025	1.4
Totals	227000	0.69	89
Totals >1.0	39800	0.21	69.5

13. The results of the colorimetric and chemical analyses of the spray as caught on the choloroform-filled plates are given in Table II below. The mean ratio of H content of the plates by analysis to charging content by colorimetric estimation of dye, was 0.65. This figure was obtained by giving the ratio found for each plate a weight proportional to the ground contamination density found from the total amount of dye in the plate. Since the H content of the original charging was 71 % H, it follows that the mean loss of H due to evaporation was approximately 8 % over the range of positions investigated (70 yards downwind of A/C track to 170 yards downwind).

TABLE II

Position on Layout	Amount of charging caught in plate (mg.)	Ratio H content of plate (by Br.) / Charging (by dye)
J 9	23	0.65
13	23	0.64
17	62	0.68
21	62	0.70
25	12	0.63
29	3.0	0.63
G 9	35	0.66
13	70	0.59
17	41	0.67
21	13	0.69
25	8	0.63
29	8	0.63
L 9	51	0.62
13	84	0.68
17	49	0.68
21	39	0.69
25	45	0.68
29	19	0.65

Ratio of H content of original charging to weight of charging was 0.71

Appendix III (cont.)

Drop Spectrum Produced

14. By counting and sizing the stains found on the filter papers where contamination was not too heavy, and on the photographic papers where contamination was heavy the drop spectrum at each point on Row E was obtained. From a knowledge of the contamination density at each point the spectrum was obtained for all spray reaching the ground from the upwind edge of the contamination to a point 235 yards downwind of this. (Contamination began at line 4 on Row E, and extended to line 41). The percentage by weight of drops in various size groups is given below.

Size Group drop wt. mg.	Size Group drop diam. mm.	% by weight of total contamination found on Row E.
> 0.01	> 0.24	32
0.01 - 0.025	0.24 - 0.33	31
0.025 - 0.05	0.33 - 0.41	16
0.05 - 0.10	0.41 - 0.52	12
0.10 - 0.25	0.52 - 0.70	6
> 0.25	> 0.70	3

Effects on Observers

15. At 8 hours

(i) The men were examined 8 hours after zero. At this time one man showed extensive erythema and oedema of his back from shoulders to waist and a small vesicle was apparent in the region of the right shoulder blade.

(ii) Thirteen men showed areas of extensive erythema, varying from areas in the shoulder regions to extensive erythema involving the entire back.

(iii) Six men had faint areas of erythema, involving the areas of one or both shoulders.

(iv) Fifteen men showed no effects.

16. At 24 hours

(i) Five men showed areas of extensive vesication with erythema, and oedema extending from the shoulders to the belt line.

(ii) Seven men had areas of pin point vesication with erythema and oedema varying from localized areas in the region of the windows on the shoulders to extensive areas involving the entire back.

(iii) Three men showed definite areas of erythema, and oedema of the back, extending across the areas between the two windows onthe shoulders.

(iv) Six men showed definite areas of erythema, demarcated by the windows on both shoulders.

(v) Eleven men showed faint erythema on one or both shoulders in the region of the windows.

(vi) Only 3 men showed nil effects.

19. At 48 hours

(i) Ten men showed large vesicles with areas of erythema and oedema. The erythema varied from areas on the shoulders to extensive areas involving the shoulders and back, and in one case extending down the natal cleft.

(ii) Five men showed areas of pin point vesication with erythema, and oedema of the shoulders extending down the back to the belt line in some cases.

Appendix III (cont.)

17. (cont.)

(iii) Two men had areas of erythema and oedema of the shoulders.

(iv) Four men had areas of erythema involving the skin in the region of the windows on the shoulders.

(v) Ten men had faint erythema of one or both shoulders in the region of the windows.

(vi) Four men showed no effects.

18. At 72 hours

The only change at this time was one case of erythema and oedema which had subsided and was now classed as erythema.

19. By seven days, most of the areas were healing, even on the more severely burned cases and pigmentation was quite well developed in the majority of cases. For a detailed description of lesions see the Addendum to this Appendix.

20. In no case did an observer become sufficiently contaminated in the region of the collar bone for any lesions to develop which could be attributed to the windows in this area.

21. The correlation between ground contamination in the vicinity of an observer and the physiological effect of the spray on the observer is given in Table III, (Part A). The data are also arranged in this Table (Part B) to demonstrate the correlation between contamination density on the observers back and the physiological effects on the observer.

22. Of the 16 observers who were classified as casualties (see note at beginning of Addendum to this Appendix) 8 had been performing outdoor fatigues for 4 hours after the spray, while 8 had been sitting or lying about in a room at 75°F for this time.

23. The contamination found on observers backs have been compared in Table IV with the contamination to be expected from a knowledge of wind speed, drop size, and ground contamination. The geometric mean ratio of calculated to observed vertical contamination density for 34 observers is 1.6.

TABLE III.1

	Part "A" Observer	Ground Contamination Density near Observer (g/sq.m.)	Dominant Drop Size mg. wt.	Dominant Drop Size mm. diam.	Physiological Effect	* Casualty	Part "B" Observer	Contamination Density on Observer's Back (g/sq.m.)	Physiological Effect	* Casualty
(w)	E 13	5.2	0.020	0.30	V E +	Yes	E 17	10.5	V E +	Yes
(w)	G 13	4.4	0.025	0.33	V E +	Yes	K 13	10.5	V E +	Yes
	J 17	3.8	0.025	0.33	E	No	L 13	10.5	V E +	Yes
(w)	E 19	3.7	0.010	0.24	PPV E +	Yes	E 19	9.0	PPV E +	Yes
	K 13	3.4	0.035	0.37	V E +	Yes	E 13	7.6	V E +	yes
	L 13	3.0	0.025	0.33	V E +	Yes	H 17	7.0	V E +	Yes
	N 13	2.7	0.035	0.37	V E +	Yes	L 19	6.0	V E +	Yes
	J 19	2.7	0.035	0.37	E -	No	E 21	5.4	V E +	Yes
	H 13	2.6	0.050	0.41	PPV E +	Yes	M 13	4.9	PPV E +	Yes
(w)	E 21	2.5	0.010	0.24	V E +	Yes	G 13	4.8	V E +	Yes
(w)	E 17	2.2	0.040	0.39	PPV E +	Yes	N 13	3.9	V E +	Yes
	J 21	2.2	0.025	0.33	E	No	G 21	3.8	PPV E +	Yes
	L 17	2.1	0.020	0.30	PPV E +	Yes	L 17	3.7	PPV E +	Yes
(w)	G 17	2.0	0.025	0.33	E -	No	J 21	3.6	E	No
(w)	G 19	1.8	0.050	0.41	E -	No	G 17	3.1	E	No
(w)	H 17	1.7	0.050	0.41	V E +	Yes	N 17	2.5	E -	No
(w)	H 19	1.6	0.025	0.33	E +	No	N 19	2.1	PPV E +	Yes
(w)	H 21	1.4	0.025	0.33	E -	No	L 25	2.0	E	No
	N 17	1.4	0.020	0.30	E -	No	J 13	2.0	V E +	Yes
	N 19	1.2	0.025	0.33	PPV E +	Yes	H 19	1.6	E +	No
	N 21	1.1	0.020	0.30	E	No	G 19	1.6	E -	No
	L 19	1.1	0.025	0.33	V E +	Yes	K 19	1.6	PPV E +	Yes
	L 21	1.1	0.010	0.24	Nil	No	G 25	1.5	E -	No
	L 25	1.1	0.010	0.24	E	No	J 19	1.4	E -	No
(w)	E 25	1.0	0.010	0.24	E -	No	K 17	1.4	E	No
	J 13	1.0	0.050	0.41	V E +	Yes	J 25	1.3	E	No
	K 17	1.0	0.050	0.41	E	No	N 21	1.2	E	No
	K 19	1.0	0.010	0.24	PPV E +	Yes	N 25	0.94	E -	No
	K 21	1.0	0.010	0.24	Nil	No	H 21	0.65	E -	No
	N 25	1.0	0.010	0.24	E -	No	K 21	0.62	Nil	No
	J 25	0.6	0.025	0.33	E	No	J 17	0.61	E	No
(w)	H 25	0.5	0.010	0.24	Nil	No	K 25	0.44	E	No
	K 25	0.47	0.010	0.24	E	No	E 25	0.29	E -	No
(w)	G 21	0.43	0.025	0.33	PPV E +	Yes	L 21	0.17	Nil	No
(w)	G 25	0.18	0.010	0.24	E -	No	H 25	trace	Nil	No.

(w) . These men were working on outdoor fatigues during the four - hour wearing period after the trial.

* The decision as to whether or not an observer was classified as a casualty was based on the severity of the lesions which it was considered would have occurred had the observer been exposed without impervious clothing.

Appendix III (cont.)

TABLE IV

Observer	Contamination densities, g/sq.m. Ground	Calc. Vertical	Obs. Vertical	Ratio Calc./Obs.
E 13	5.2	13.1	7.6	1.72
G 13	4.4	10.1	4.8	2.1
J 17	3.8	8.7	0.61	14.3
E 19	3.7	10.6	9.0	1.18
K 13	3.4	7.15	10.5	0.68
L 13	3.0	0.89	10.0	1.83
N 13	2.7	5.7	3.9	1.46
J 19	2.7	5.7	1.4	4.06
H 13	2.6	5.0	4.9	1.02
E 21	2.5	7.15	5.4	1.32
E 17	2.2	4.25	10.5	0.40
J 21	2.2	5.0	3.6	1.39
L 17	2.1	5.3	3.7	1.43
G 17	2.0	4.6	3.1	1.48
G 19	1.8	3.4	1.6	2.12
H 17	1.7	3.2	7.0	0.46
H 19	1.6	3.7	1.6	2.30
H 21	1.4	3.2	0.65	4.95
N 17	1.4	3.2	2.5	1.28
N 19	1.2	3.74	2.1	1.31
N 21	1.1	2.77	1.2	2.30
L 19	1.1	2.52	6.0	0.42
L 21	1.1	3.15	0.17	18.5
L 25	1.1	3.14	2.0	1.57
E 25	1.0	2.86	0.29	9.9
J 13	1.0	1.91	2.0	0.95
K 17	1.0	1.91	1.4	1.36
K 19	1.0	2.86	1.6	1.79
K 21	1.0	2.86	0.62	4.6
N 25	1.0	2.86	0.94	3.04
J 25	0.6	1.37	1.3	1.06
H 25	0.5	1.13	trace	----
K 25	0.47	1.35	3.8	0.26
G 21	0.43	0.98	3.8	0.25
G 25	0.18	0.515	1.5	0.33
			Geometric mean	1.63

ADDENDUM TO APPENDIX III

DETAILED DESCRIPTION OF LESIONS

The decision as to whether or not an observer was classified as a casualty was based on the severity of the lesions which it was considered would have occurred had the observer been exposed without impervious clothing, extrapolating from the lesions resulting from exposure of three areas 4 x 4 inches on the back, and two 4 x 4 inch areas in front.

It was difficult to make this extrapolation with accuracy. Consequently in this appendix the observers have been divided into four groups: (1) casualty, (2) probable casualty, (3) possible casualty (4) non-casualty. For the tables in the body of the report all first three groups are classed as casualties.

Casualties are definite, showing extensive areas of vesication, erythema and œdema.

Probable casualties show small vesicles or areas of pin-point vesication which do not become confluent, but which, if they occurred on sensitive areas of the body, would likely result in the man becoming a casualty.

Possible casualties may show areas of pin-point vesication which are delayed in appearing or which cover a small area of the body. These lesions, if they occurred in more sensitive areas of the body, might result in the man becoming a casualty.

Non-casualties show areas of erythema and œdema or less; with no tendency to vesicate.

Detailed descriptions of the physiological effects found on the various observers are given below.

(w) LINE E, Position 13.

Ground contamination - 5.2 g/sq.m.
Contamination on Observer's back - 7.6 g/sq.m.
Dominant drop size - 0.020 mg. (0.30 mm.) diam.

At 8 hours this man showed erythema across the entire upper back and down the mid-line to the waist. At 24 hours: left shoulder - pin-point vesication 6.0 x 2.0 cm. on shoulder blade; right shoulder - pin-point vesication 4.0 x 2.8 cm. on shoulder blade. Both these areas were surrounded by erythema and oedema 30 x 30 cm. At 48 hours: left - vesication 3 x 1.8 cm. surrounded by pin-point vesication 8 x 4 cm. Erythema in left armpit; right - pin-point vesication 4 x 3 cm.; mid-line - pin-point vesication 13 x 3 cm. This whole area surrounded by an area of erythema and oedema 38 x 37 cm. At 72 hours: Left shoulder - area of ruptured vesicles and pin-point vesicles 20 x 20 cm. The skin was pigmenting. (Casualty).

(w) LINE E, Position 17.

Ground contamination - 2.2 g/sq.m.
Contamination on Observer's back - 10.5 g/sq.m.
Dominant drop size - 0.040 mg. (0.39 mm.) diam.

At the 8-hour examination this man showed erythema of the upper back. At 24 hours: the back showed erythema going on to erythema and oedema over an area 24 x 26 cm. At 48 hours: Erythema and oedema of entire back 26 x 40 cm. There were a few small PPV's in mid-line. At 72 hours: Pin-point vesicles and devitalized skin had increased to cover an area 10 x 20 cm. on the mid-line and extending up to the left shoulder. Erythema and oedema surrounded this area 23 x 38 cm. At 96 hours: There was erythema of the left armpit. The oedema of the back had disappeared and the erythema was fading.
(Possible casualty.)

(w) These men were working on outdoor fatigues during the four - hour wearing period after the trial.

ADDENDUM TO APPENDIX III

(w) LINE E, Position 19.

Ground contamination - 3.7 g/sq.m.
Contamination on Observer's back - 9.0 g/sq.m.
Dominant drop size - 0.010 mg. (0.24 mm.) diam.

At the 8-hour examination this man showed extensive erythema of the upper back. At 24 hours: There was erythema and oedema of the upper back 30 x 30 cm. There were scattered pin-point vesicles on the left shoulder 4.0 x 2.5 cm. At 48 hours: The erythema and oedema of the back had increased to 40 x 32 cm. The pin-point vesication on the left shoulder had increased to an area of 12 x 8 cm. There was erythema at the posterior border of both armpits. At 96 hours: There was erythema and oedema of both armpits. Pin-point vesication of the left shoulder was 11 x 10.5 cm. and there was an area of pin-point vesication on the right shoulder 4 x 9 cm. Erythema and oedema surrounding this area was 30 x 38 cm. (Probable casualty.)

(w) LINE E, Position 21.

Ground contamination - 2.5 g/sq.m.
Contamination on Observer's back - 5.4 g/sq.m.
Dominant drop size - 0.010 mg. (0.24 mm.) diam.

At 8 hours: this man showed extensive erythema of the back. At 24 hours: Several huge vesicles had appeared! - left shoulder - vesicle 4.5 x 3 cm.; coalescent vesicles - 11.5 x 10.0 cm.; right shoulder - coalescent vesicles 13.0 x 10 cm.; small of back - vesicles 2.5 x 1.5 cm. This area was surrounded by an area of erythema and oedema 31 x 34 cm. At 48 hours: It was difficult to see much change at 48 hours except the coalescent vesicles had become confluent. At 96 hours: Two small vesicles had appeared, one on each side at the level of the lower border of the scapula, (1) 1.5 x 1.0 cm. and (2) 2.0 x 1.5 cm. (Casualty.)

(w) LINE E, Position 25.

Ground contamination - 1.0 g/sq.m.
Contamination on Observer's back - 0.29 g/sq.m.
Dominant drop size - 0.010 mg. (0.24 mm.) diam.

At 8 hours there was a faint suggestion of erythema over the left shoulder. At 24 hours there was faint erythema of the left shoulder 9.5 x 8.0 cm. At 48 hours the erythema was fading (9 x 7 cm.). At 96 hours the erythema had faded. (Non-casualty.)

(w) LINE G, Position 13.

Ground contamination - 4.4 g/sq.m.
Contamination on Observer's back - 4.8 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At the 8-hour examination there was extensive erythema of the entire back. At 24 hours there were several large vesicles over the back (1) 8 x 6 cm., (2) 3 x 3 cm., (3) 1 x 1 cm., (4) 1.8 x 1.0 cm., (5) 5.5 x 2.7 cm. The entire area was joined by coalescent small vesicles 28 x 27 cm. This whole area was surrounded by erythema and oedema 30.0 x 36.0 cm. At 48 hours the entire back was covered by coalescent vesication 30 x 30 cm. At 96 hours the large vesicle roofs had separated, the small coalescent vesicles had collapsed and the entire area was pigmenting. Faint erythema of the left armpit was present. (Casualty.)

(w) LINE G, Position 17.

Ground contamination - 2.0 g/sq.m.
Contamination on Observer's back - 3.1 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours there was questionable erythema of the left shoulder. At 24 hours there was faint erythema of the left shoulder 7.0 x 5.0 cm. At 48 hours both shoulders showed faint erythema. At 96 hours both shoulders were pigmenting. (Non-casualty.)

ADDENDUM TO APPENDIX III

(w) LINE G, Position 19.

Ground contamination - 1.8 g/sq.m.
Contamination on Observer's back - 1.6 g/sq.m.
Dominant drop size - 0.050 mg. (0.41 mm.) diam.

At 8 hours there was no evidence of erythema. At 24 hours there was faint erythema of the left shoulder 4.0 x 3.0 cm. At 48 hours this was fading. At 96 hours there was slight pigmentation in this area.

(Non-casualty.)

(w) LINE G, Position 21.

Ground contamination - 0.43 g/sq.m.
Contamination on Observer's back - 3.8 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours there was erythema of the upper back. At 24 hours there was erythema going on to erythema and oedema across the shoulders and extending down the mid-line of the back 27 x 23 cm. At 48 hours the erythema and oedema had increased to cover an area 32 x 30 cm. There was pin-point vesication on the left shoulder 4 x 3 cm. and an area 6 x 5 cm. on the right shoulder. At 96 hours the pin-point vesicles had collapsed and the erythema was fading.

(Possible casualty.)

(w) LINE G, Position 25.

Ground Contamination - 0.18 g/sq.m.
Contamination on Observer's back - 1.5 g/sq.m.
Dominant drop size - 0.010 mg. (0.24 mm.) diam.

At the 8-hour observation there were two faint areas of erythema, one over each shoulder. At 24 hours there was faint erythema of both shoulders, left shoulder - 7.0 x 7.0 cm.; right shoulder - 9.0 x 8.0 cm. At 48 hours these areas were unchanged. At 96 hours both these areas were pigmenting.

(Non-casualty.)

(w) LINE H, Position 15

Ground contamination - 2.6 g/sq.m.
Contamination on Observer's back - 4.9 g/sq.m.
Dominant drop size - 0.050 mg. (0.41 mm.) diam.

At 8 hours this man showed erythema over both shoulders. At 24 hours there was erythema going on to erythema and oedema extending over both shoulders and down the back 30 x 23 cm. There was pin-point vesication of the left shoulder 4 x 3 cm. At 48 hours there was erythema of both armpits and the erythema and oedema had extended to 35 x 36 cm. There were two vesicles on the left shoulder 1 x 1 cm. and 1.5 x 1.3 cm. This area was surrounded by pin-point vesication 8.5 x 5.8 cm. At 72 hours the areas of the windows on the shoulders were becoming desquamated. There was one vesicle on the left shoulder 3 x 2.2 cm. surrounded by pin-point vesication 10.5 x 8.0 cm. (Probable casualty.)

(w) LINE H, Position 17.

Ground contamination - 1.7 g/sq.m.
Contamination on Observer's back - 7.0 g/sq.m.
Dominant Drop Size - 0.050 mg. (0.41 mm.) diam.

At 8 hours this man showed extensive erythema of the upper back and shoulders. At 24 hours he showed a vesicle 4.5 x 3.5 cm. surrounded by numerous small vesicles on the left shoulder. This area was surrounded by erythema and oedema 11.5 x 10.0 cm. The right shoulder showed a vesicle 5.5 x 4.5 cm. surrounded by pin-point vesication 9.0 x 9.0 cm. The whole of the right shoulder was involved in erythema and oedema 24.0 x 13.5 cm. There were three small vesicles in the mid-line. At 48 hours there was very little change except that the erythema and oedema had become confluent to cover an area 38 x 39 cm. and erythema had developed in both armpits. At 72 hours the blister roofs had sloughed and pigmentation was developing between the sloughed area. (Casualty).

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(w) LINE H, Position 19.

Ground contamination - 1.6 g/sq.m.
Contamination on Observer's back - 1.6 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours this man showed erythema of both shoulders in the region of the windows. At 24 hours there was erythema and oedema of both shoulders in the region of the windows; left shoulder - 12 x 12 cm.; right shoulder 13 x 11.5 cm. At 48 hours these areas were unchanged. At 72 hours the oedema had subsided and the areas were beginning to pigment. (Non-casualty.)

(w) LINE H, Position 21.

Ground contamination - 1.4 g/sq.m.
Contamination on Observer's back - 0.65 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours nothing could be seen. At 24 hours there was faint erythema of the left shoulder. At 48 hours this had faded. (Non-casualty.)

(w) LINE H, Position 25.

Ground contamination - 0.5 g/sq.m.
Contamination on Observer's back - Trace.
Dominant drop size -0.010 mg. (0.24 mm.)diam.

At no time was there any lesion. (Non-casualty.)

LINE J, Position 13.

Ground contamination - 1.0 g/sq.m.
Contamination on Observer's back - 2.0 g/sq.m.
Dominant drop size - 0.050 mg. (0.41 mm.) diam.

At 8 hours this man showed erythema of his shoulders. At 24 hours he showed erythema going on to erythema and oedema of his back 31 x 31 cm. There were pin-point vesicles on his left shoulder 6 x 3.0 cm. The areas were joined by a confluent morbilliform type of rash. On questioning it was found that he had received an H burn on his forearm 1½ months previously. At 48 hours the erythema and oedema had increased to 39 x 36 cm. The left shoulder showed pin-point vesication 9.5 x 6.0 cm. and the right shoulder showed an identical area 9.5 x 6.0 cm. There was a small area of pin-point vesication on the mid-line. At 72 hours the periphery of the area was pigmenting and the oedema was subsiding. There was an area of devitalized skin on the mid-line of the back 15 x 22 cm. At 96 hours there were two vesicles on the left shoulder 2.2 x 4 cm. and 1.5 x 2.2 cm. There was one vesicle on the right shoulder 3.8 x 2.1 cm. surrounded by pin-point vesication 10 x 12 cm. (Casualty.)

LINE J, Position 17.

Ground contamination - 3.8 g/sq.m.
Contamination on Observer's back - 0.61 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours this man showed faint erythema of the right shoulder. At 24 hours there was erythema of the right shoulder 17.5 x 9.0 cm. At 48 hours the erythema had decreased to 9 x 9.5 cm. At 72 hours there was a small area of desquamation on the right shoulder. (Non-casualty.)

LINE J, Position 19.

Ground contamination - 2.7 g/sq.m.
Contamination on Observer's back - 1.4 g/sq.m.
Dominant drop size - 0.035 mg. (0.37 mm.) diam.

At 8 hours no erythema was visible. At 24 hours there was faint erythema of the right shoulder 5 x 5 cm. At 48 hours the erythema, though faint, had increased to 4 x 7 cm. At 72 hours the erythema had faded. (Non-casualty.)

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LINE J, Position 21.

Ground contamination - 2.2 g/sq.m.
Contamination on Observer's back - 3.6 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours this man showed faint erythema of his shoulders. At 24 hours there was erythema of his left shoulder 11.0 x 8.0 cm. The right shoulder showed faint erythema 5.0 x 4.0 cm. At 48 hours these areas were unchanged. At 72 hours all erythema was fading. (Non-casualty.

LINE J, Position 25.

Ground contamination - 0.6 g/sq.m.
Contamination on Observer's back - 1.3 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours there was faint erythema of both shoulders. At 24 hours there was erythema of both shoulders, left - 8.0 x 5.0, right - 8.0 x 8.0 cm. At 48 hours these areas were unchanged. At 72 hours both shoulders were pigmenting. (Non-casualty.)

LINE K, Position 13.

Ground contamination - 3.4 g/sq.m.
Contamination on Observer's back - 10.5 g/sq.m.
Dominant drop size - 0.035 mg. (0.37 mm.) diam.

At 8 hours this man showed erythema of the back. At 24 there was pin-point vesication on both the left and right shoulders. shoulder - 10 x 7 cm., right shoulder - 10 x 7.5 cm. These areas were surrounded by erythema and oedema 40 x 43 cm. which extended onto both left and right armpits. There was a morbilliform rash superimposed on the redness. On questioning the man, it was found that he had received an H burn on the right forearm nine months previously. At 48 hours there was a vesicle 5.5 x 2.4 cm. on the left shoulder surrounded by pin-point vesication 10 x 8 cm. There was a vesicle 5.5 x 5.3 cm. on the right shoulder surrounded by pin-point vesication 12 x 11 cm. The entire back to the beltline was involved in erythema and oedema which also extended onto the armpits. At 96 hours these lesions were improving. (Casualty.)

LINE K, Position 17.

Ground contamination - 1.0 g/sq.m.
Contamination on Observer's back - 1.4 g/sq.m.
Dominant drop size - 0.050 mg. (0.41 mm.) diam.

At 8 hours this man showed faint erythema of both shoulders. At 24 hours there was erythema of the right shoulder 9.5 x 11.0 cm. and faint erythema of the left shoulder 9 x 7 cm. At 48 hours these areas were unchanged. At 72 hours the erythema was fading on both shoulders. (Non-casualty.)

LINE K, Position 19.

Ground contamination - 1.0 g/sq.m.
Contamination on Observer's back - 1.6 g/sq.m.
Dominant Drop Size - 0.010 mg. (0.24 mm.) diam.

At 8 hours this man showed erythema of his shoulders. At 24 hours he showed erythema going on to erythema and oedema 30 x 17 cm. with scattered pin-point vesicles through this area. At 48 hours the area had increased to erythema and oedema 30 x 35 cm. with scattered pin-point vesicles throughout the area. There was a faint erythema of the right armpit. At 72 hours there was erythema of both armpits and the skin on the back was pigmenting. There were several small pustules formed on the right shoulder blade 2 x 5 cm. (Possible casualty.)

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LINE K, Position 21.

Ground contamination - 1.0 g/sq.m.
Contamination on Observer's back - 0.62 g/sq.m.
Dominant drop size - 0.010 mg. (0.24 mm.) diam.

At no time did this man show any sign of erythema. (Non-casualty.)

LINE K, Position 25.

Ground contamination - 0.47 g/sq.m.
Contamination on Observer's back - 0.44 g/sq.m.
Dominant drop size - 0.010 mg. (0.24 mm.) diam.

At 24 hours this man showed erythema of both shoulders in the region of the windows. Left shoulder - 12 x 10.5 cm.; right shoulder - 14 x 13 cm. At 48 hours these areas were unchanged. At 72 hours there was desquamation of the right shoulder over an area 7 x 9 cm. (Non-casualty.)

LINE L, Position 13.

Ground contamination - 3.0 g/sq.m.
Contamination on Observer's back - 10.5 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours this man showed extensive erythema of the entire back. At 24 hours there were several large vesicles present: right shoulder - 6.5 x 4.0 cm., 5.0 x 4.5 cm. These two were joined by a confluent area of pin-point vesication 12.5 x 10 cm. Right shoulder - vesicle 3 x 2.5 cm. surrounded by confluent small vesicles 12.5 x 9.5 cm. There were several vesicles in the mid-line starting from the level of the lower border of the scapula and extending down past the small of the back: (1) 3.5 x 3.5 cm. (2) 7.0 x 5.5 cm., (3) 6.0 x 4.0 cm., (4) 4.5 x 3.7 cm. (5) 5.5 x 6.0 cm. (6) 7.1 x 2.5 cm. This whole area was joined by confluent small vesicles 42 x 16 cm. The whole of the back was involved in erythema and oedema 45.0 x 60.0 cm. which extended down to and involved the natal cleft. At 48 hours the areas of small vesicles were coalescing. At 96 hours erythema and oedema of the left armpit. The large vesicle roofs had sloughed, the small coalescent vesicles had collapsed and there was a dusky pigmentation to the entire area. (Casualty.)

LINE L, Position 17.

Ground contamination - 2.1 g/sq.m.
Contamination on Observer's back - 3.7 g/sq.m.
Dominant drop size - 0.020 mg. (0.30 mm.) diam.

At 8 hours this man showed erythema of his shoulders and mid-line of his back. At 24 hours there was erythema going on to erythema and oedema of the right shoulder 12 x 10.5 cm., with a few scattered pin-point vesicles. There was erythema of the left shoulder 6 x 9 cm. There was faint erythema progressing to sharp erythema in the mid-line of the back 11 x 5 cm. At 48 hours the erythema had become confluent and covered an area 31 x 30 cm. Pin-point vesication was unchanged. At 72 hours pin-point vesication was present on the left and right shoulders and on the mid-line of the back: left shoulder - 8 x 5 cm., right shoulder - 7 x 5 cm., Mid-line of back - 18 x 4 cm. (Probable Casualty.)

LINE L, Position 19.

Ground contamination - 1.1 g/sq.m.
Contamination on Observer's back - 6.0 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours this man showed erythema of the shoulders and mid-line of the back. At 24 hours he showed erythema going on to erythema and oedema of the back 30 x 32 cm. There were two small vesicles below the right shoulder blade 1 x 1 and 0.7 x 0.4 cm. At 48 hours one more vesicle had formed on the right shoulder 1 x 0.5 cm. There was erythema of both armpits. At 72 hours one more vesicle had appeared on the mid-line. Pin-point vesicles extended

ADDENDUM TO APPENDIX III

down the mid-line 19 x 12 cm. Pin-point vesicles on the left shoulder covered an area 8 x 6 cm. At 96 hours a rash appeared in the mid-axillary line of the right side and extended around to the front of the abdomen on that side. This rash faded in another 24 hours. (Probable Casualty.)

LINE L, Position 21.

Ground contamination - 1.1 g/sq.m.
Contamination on Observer's back - 0.17 g/sq.m.
Dominant drop size - 0.010 mg. (0.24 mm.) diam.

At no time did any lesions appear. (Non-casualty.)

LINE L, Position 25.

Ground contamination - 1.1 g/sq.m.
Contamination on Observer's back - 2.0 g/sq.m.
Dominant drop size - 0.010 mg. (0.24 mm.) diam.

At 8 hours this man showed faint erythema of both shoulders. At 24 hours there was faint erythema of the left shoulder 9 x 8.5 cm. and well defined erythema of the right shoulder 8.5 x 8.5 cm. At 48 hours these areas were the same. At 72 hours the erythema on both shoulders was fading. (Non-casualty.)

LINE N, Position 13.

Ground contamination - 2.7 g/sq.m.
Contamination on Observer's back - 3.9 g/sq.m.
Dominant drop size - 0.035 mg. (0.37 mm.) diam.

At 8 hours this man showed erythema of the entire back. At 24 hours there were numerous areas of coalescent small vesicles: left shoulder - (1) 6 x 4 cm., (2) 3 x 2 cm.; right shoulder (1) 6.8 x 5.2 cm.; mid-line-(1) 24 x 5 cm. There were 2 vesicles on this area in the mid-line 2.1 x 2.5 and 2.2 x 2.5 cm. The entire area was surrounded by erythema and oedema 31 x 36 cm. At 48 hours the vesicles on the shoulder and the mid-line had become confluent. At 96 hours the left shoulder had a vesicle 5.2 x 3.5 cm. surrounded by collapsed small vesicles 10 x 10 cm., and the right shoulder, extending down the mid-line, pin-point vesicles 15 x 5 cm. In the mid-line was (1) vesicle 3.5 x 3.2 cm., and (2) vesicle 5.5 x 2.8 cm. (Casualty.)

LINE N, Position 17.

Ground contamination - 1.4 g/sq.m.
Contamination on Observer's back - 2.5 g/sq.m.
Dominant drop size - 0.020 mg. (0.30 mm.) diam.

At 8 hours there was faint erythema of both of his shoulders. At 24 hours there was faint erythema of both shoulders: left - 5 x 8 cm., right - 4 x 2 cm. At 48 hours these areas were unchanged. At 72 hours both these areas were fading in color. (Non-casualty.)

LINE N, Position 19.

Ground contamination - 1.2 g/sq.m.
Contamination on Observer's back - 2.1 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours this man showed erythema of both shoulders in the region of the windows. At 24 hours there were a few scattered pin-point vesicles on the left shoulder surrounded by an area of erythema and oedema 8.5 x 9 cm. There was erythema and oedema of the right shoulder 8 x 8 cm. At 48 hours there was pin-point vesication on the left shoulder 5 x 3 cm. surrounded by erythema and oedema 12 x 11 cm. There was pin-point vesication of the right shoulder 4 x 2 cm. surrounded by erythema and oedema 12 x 9 cm. At 72 hours these areas of pin-point vesication were unchanged and the oedema was subsiding. (Possible casualty.)

APPENDIX IV

Classification of Casualties from Mustard Burns
(after Suffield Field Report 97)

Class 1

A casualty under any circumstances, regardless of how willing the subject is to continue his duties or how acute the situation. Mobility of one or both limbs is completely impeded or a large area of the trunk (½ or more of the front or back) is involved by vesication.

Class 2

"Just not a casualty". Mobility of one or more limbs is limited but not completely impeded by the burns in their full maturity. Would become a casualty if required to do any work involving strenuous exercise, such as running ½ mile or march-2 miles.

For purposes of Assessment, these classes are in the CASUALTY Group.

Class 3

Not a casualty, although burns may be prominent and wide-spread. The mobility of the limbs is not interfered with and is unlikely to be interfered with even on strenuous exercise.

Class 4

Not a casualty. Trivial and insignificant burns.

For purposes of Assessment, these classes are in the NON-CASUALTY Group.

5244210 Suffield Report Book

EXTRACT FROM Z 15627 COPY ANT attached

CHEMICAL WARFARE OTTAWA FEB 10 1945 General CANADA

MAR 14 1945 CANADA

PORTON'S COMMENTS ON SUFFIELD REPORT NO 121

1. This very valuable report deals with trials of low spray of Levinstein unthickened mustard gas from M.10 tank at an air temperature of 60-70°F in wind speeds of 8 to 15 mi/hr. on observers wearing normal service clothing and respirators.

2. The results show clearly that casualties are to be expected in the area contaminated to an extent greater than 2 g/m^2 and a high percentage in the area contaminated with 3 g/m^2. These findings are in reasonably good agreement with the so-called "1942 assessment" (vide Porton Memorandum No.14) in which a ground contamination density of 3 g/m^2 was given as the minimum which will cause casualties in cool European conditions when the drop-size is less than 0.5 mm. diameter. It is very useful to have had the upper limit of approximately 4 g/m^2 on the man's clothing corresponding to 3 g/m^2 on the ground (p.6, para.29), clearly fixed by experiment.

3. We have no general comments to offer on the physiological assessment, which appears to be sound. It is now for consideration whether any other trials with aircraft spray, using human observers, are really necessary.

4. It is noted that one M.10 tank contaminated 20,000 sq. yds. in excess of 2 g/m^2 from 50 ft. at an aircraft speed of 215 mi/hr. and that it was estimated that there was a 50% casualty risk in this area.

5. Under the conditions of the experiments the loss by evaporation was not serious. However, at higher aircraft speeds when increased shatter is to be expected and at higher air temperatures, an appreciable proportion of the charging may evaporate on the way down to the ground. It is therefore desirable that trials should be done to determine the drop size-distribution and area contamination at the highest air speeds likely to be employed operationally and also, preferably, at high air temperatures. We are putting forward proposals for trials of this nature in India.

6. The experiments covered by this Report were taken into consideration when formulating the recommendation recently made from Porton that unthickened chargings are suitable for use from M10 tanks for low spray. They furnish evidence, however, only as far as temperate conditions and moderate aircraft speeds are used.

Comments on Details

7. The report brings out very clearly the difference in contamination density found (a) on a standing man's back and (b) on the ground around him. Assuming that a man's back is a perfect impactor, the contamination density when he is standing may be obtained theoretically from that on the ground around him by multiplying by the tangent of the angle of strike, i.e., by the ratio of the wind speed to the terminal velocity of the drops. For a constant wind speed the ratio, therefore, increases with decreasing drop-size. To quote an example from the report, in a 15 mi/hr. wind, the ratio for 0.5 mm. drops is about 2.75, whereas for 0.2 mm. drops it is 6.3.

8. Trials at Porton in 1940 showed that the theoretical ratio was not attained and this was attributed to the effect of eddying of air round standing men. In the Suffield report it is estimated that the density of contamination on a man's back was, on the average, approximately 60% of the theoretical density calculated from the ground contamination near the man. This discrepancy may have been due partly to air eddies and also partly to the man's body not acting as a perfect impactor. The predominating drop size to which the observers were exposed in the Suffield trials varied from 0.2 to 0.4 mm. If a man's body be considered as a cylinder of 40 cm. diameter, it is calculated that it would have an efficiency of about 65% as an

p.t.o.

impactor for 0.2 mm. drops in an 8 mi/hr. wind and of about 85% in a 15 mi/hr. wind. For 0.4 mm. drops the figures are about 95% and 100% respectively. In the Porton trials the drops were sufficiently large for the impaction efficiency to be 100%.

9. It is noted that the observers stood facing downwind and that windows were cut in their impermeable clothing. Although these were chosen to include positions where the clothing is "normally loose over the skin", the observers in fact either lay or sat about after being sprayed or took part in outdoor fatigues (shovelling, digging, etc.). Under all these conditions there would be an optimum chance for development of burns from contaminated sites on the backs of clothing. In actual operations, many men would be facing the spray especially if they were taking offensive action against the attacking aircraft. Nevertheless, it is considered that the casualty effects through clothing would be at least as severe as estimated from the Suffield trials.

Chief Superintendent, C.D.E.
Station

6-B-37-790-6

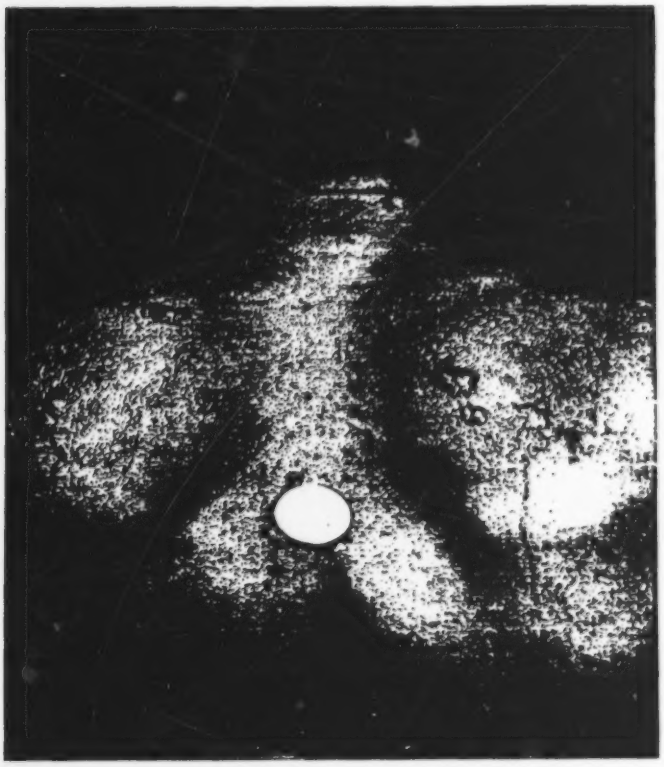
Plate I

Observer 13F Appendix I. Ground Contamination 6.6 gm./sq. m. 24 hours after spraying. One large vesicle surrounded by an area of intense erythema with pin point vesication has developed under the site of the window on the left shoulder.

6-B-37-790-9

Plate II

Observer 17G. Appendix I. Ground Contamination 4.3 gm./sq. m. 24 hours after spraying. The portions of the skin corresponding to the windows cut in the impervious clothing are occupied by vesication. Erythema spreads outwards beyond these areas, is coalescent in the mid-line, and spreads downwards towards the waist. This observer also sustained vesication on the buttocks and in the natal cleft.



6-B-37-790-1

Plate III

Observer 25F Appendix I. Ground Contamination 5.3 gm./sq. m. 24 hours after spraying. Areas of intense vesication have involved the skin beneath the windows in the impermeable clothing. Erythema has spread in all directions, is coalescent at the middle of the back and has spread downwards towards the waist. (See Plate IV)

6-B-37-790-3

Plate IV

Observer 25F Appendix I. The same observer as illustrated in Plate III. Both buttocks are involved by intense erythema and vesication spreading far beyond the limits of the skin unprotected by the impermeable clothing. Severe vesication has involved the natal cleft and has spread forwards to the perineum, scrotum, and penis. For 4 hours after the spray this observer lay or sat about on his contaminated clothing. Such behaviour frequently accentuates the severity of a lesion due to pressure of contaminated clothing on the underlying skin.

6-B-37-790-5

Plate V

Observer 13E Appendix I. Ground Contamination 4.0 gm./sq. m. 24 hours after spraying. More severe vesication has developed on the right shoulder than on the left. (See Plate VI)

6-B-37-790-4

Plate VI

Observer 13E. Appendix I. The same observer as illustrated in Plate V. Sharp erythema has extended outward from these lesions, has coalesced at the mid-line and extended inwards at the natal cleft. These lesions increased in severity over the succeeding few days.

6-B-39-969-1

Plate VII

Observer 21E Appendix III. Ground Contamination 2.5 gm./sq. m. Contamination on observer's back-5.4 gm./sq. m. (24 hours after spraying). The site of the windows in the impermeable clothing is marked by areas of pinpoint vesication including some large vesicles. The areas of pinpoint vesication are surrounded by an area of erythema and oedema.

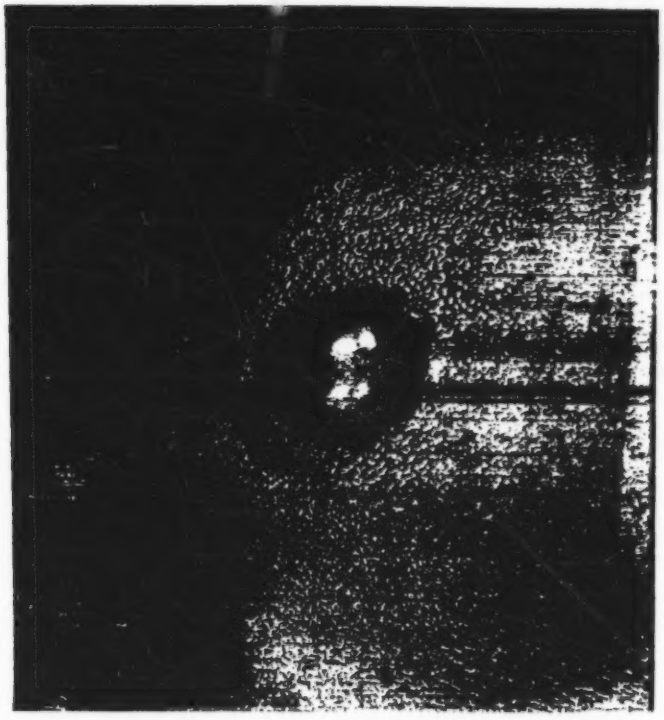


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Plate VIII

Observer 17H Appendix III. Ground Contamination 1.7 gm./sq. m. Contamination on observer's back---7.0 gm/sq. m. (24 hours after spraying). The right shoulder shows a large vesicle surrounded by pin-point vesication. The whole shoulder is involved in erythema and oedema. The left shoulder (not shown) showed similar effects.

6-B-39-969-2

Plate IX

Observer 13L Appendix III, Ground Contamination 3.0 gm/sq. m. Contamination on observer's back-10.5 gm/sq. m. (24 hours after spraying) A number of large vesicles are present surrounded by confluent areas of pin-point vesication. The whole of the back is involved in erythema and oedema which extends into the natal cleft.

6-B-39-969-3

Plate X

Observer 13G Appendix III. Ground Contamination 4.4 gm/sq. m. Contamination on observer's back---4.8 gm/sq. m. (24 hours after spraying) There are several large vesicles. The sites of the two windows on the shoulders and the windows in the middle of the back are marked by confluent areas of coalescent small vesicles. The whole of this area is surrounded by erythema and oedema.

6-B-39-969-4

Plate XI

Observer 13K Appendix III. Ground Contamination 3.4 gm/sq. m. Contamination on observer's back 10.5 gm/sq. m. (48 hours after spray). There is a large vesicle surrounded by pin-point vesication on each shoulder. The entire back to the beltline is involved in erythema and oedema which extend into the armpits.